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PONS

GEOTHERMAL DIRECT HEAT APPLICATIONS PROGRAM SUMMARY

PRESENTED

AT THE

SEMI-ANNUAL REVIEW MEETING

EL CENTRO, CALIFORNIA

APRIL 1980

U.S. DEPARTMENT OF ENERGY

GEOTHERMAL ENERGY DIVISION

DISCLAIMER

GEOTHERMAL

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ACKNOWLEDGMENTS

The project descriptions contained in this summary were prepared by the Project Teams of each of the twenty-two direct heat application projects currently in progress throughout the United States. The Department of Energy gratefully acknowledges their assistance in providing this information which will assist other potential users in assessing the economic and technical viability of the direct use of geothermal energy. Additional copies of this summary can be obtained through the Department of Energy Offices listed on page 6.

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GEOTHERMAL DIRECT HEAT APPLICATIONS

SEMI-ANNUAL REVIEW MEETING

AGENDA

TUESDAY, APRIL 15, 1980

8:30 - 9:30	Sign-in and Program Summary Distribution	
9:30 - 9:40	Opening Remarks G. S. Budney, Project Manager Geothermal Programs Energy Technology Engineering Center (ETEC)	
9:40 - 10:00	Direct Heat Applications Program Overview Eric Peterson, Program Manager Direct Heat Applications Programs DOE - Washington, D.C.	
	Agribusiness Projects Chairperson - G. S. Budney, ETEC	
10:00 - 10:20	Aquafarms International, Inc. Dr. Dov Grajcer, President Aquafarms International, Inc.	
10:20 - 10:40	Kelley Hot Springs Agricultural Center Frank B. Metcalfe, President Geothermal Power Corporation	
10:40 - 11:00	Coffee Break	
11:00 - 11:20	Utah Roses Dr. Jay Kunze, General Manager Energy Services, Inc.	
11:20 - 11:40	Diamond Ring Ranch Dr. Stanley M. Howard Professor of Metallurgical Engineering South Dakota School of Mines and Technology	
11:40 - 12:00	Questions and Answers - Agribusiness Projects	
12:00 - 1:30	Lunch	

TUESDAY, APRIL 15, 1980 (continued)

	Industrial Process Projects Chairperson - Roland Marchand, DOE-NEVADA
1:30 - 1:50	Ore-Ida Foods Processing John Austin, Project Engineer CH2M Hill - Boise
1:50 - 2:10	Madison County Food Processing Roger C. Stoker, Manager Geological Engineering Energy Services, Inc.
2:10 - 2:30	Holly Sugar Jay Seidman, Project Manager Joseph Kennedy, Assistant Project Manager TRW Energy Systems Group
2:30 - 3:00	Questions and Answers - Industrial Process Projects
3:00 - 3:20	Coffee Break
	District Heating Systems - Part I Chairperson - Ed DiBello, EG&G Idaho, Inc.
3:20 - 3:40	Reno Apartment Complex Heating Dr. David J. Atkinson, President Hydrothermal Energy Corporation
3:40 - 4:00	Susanville (California) District Heating Philip A. Edwardes, Principal Investigator City of Susanville
4:00 - 4:20	El Centro Space Heating and Cooling George Parker, City Manager City of El Centro, California
4:20 - 4:40	Monroe City (Utah) District Heating Bruce Sakashita, Project Engineer Terra-Tek
4:40 - 5:10	Questions and Answers - District Heating Systems - Part I
5:10	Adjourn
6:00 - 7:30	No-Host Social Hour - Vacation Inn Travelodge

WEDNESDAY, APRIL 16,1980

	District Heating Systems - Part II Chairperson - Ed DiBello, EG&G Idaho, Inc.
9:00 - 9:20	Boise (Idaho) District Heating Nathan Little, Project Manager CH2M Hill - Boise
9:20 - 9:40	Elko (Nevada) Space and Process Heating Sheldon Gordon, Project Engineer Chilton Engineering
9:40 - 10:00	Klamath Falls (Oregon) District Heating Harold Derrah, Assistant City Manager Klamath Falls, Oregon
10:00 - 10:20	Pagosa Springs (Colorado) Community Heating Kenneth Garing, Project Engineer Coury & Associates
10:20 - 10:50	Questions and Answers - District Heating Systems - Part II
10:50 - 11:10	Coffee Break
	Institutional Heating Systems Chairperson - Hilary Sullivan, DOE-SAN
11:10 - 11:30	Klamath County (Oregon) YMCA Brian Fitzgerald, General Director Klamath County YMCA
11:30 - 11:50	Navarro College and Memorial Hospital Ron Keeney, Project Engineer Radian Corporation
11:50 - 12:10	Utah State Prison Jeff Burks, Project Engineer Utah Energy Office
12:10 - 1:30	Lunch

WEDNESDAY, APRIL 16, 1980 (continued)

1:30 - 1:50	Warm Springs (Montana) Stste Mental Hospital Karen Barclay, Project Manager Montana Energy and MHD R&D Institute, Inc.
1:50 - 2:10	Torbett-Hutchings-Smith (T-H-S) Memorial Hospital Marshall Conover, Project Engineer Radian Corporation
2:10 - 2:30	St. Mary's Hospital James Russell, Administrator Robert Sullivan, Consultant Kirkham, Michael & Associates
2:30 - 2:50	Philip (South Dakota) Schools Dick Berg, Project Engineer Hengel, Berg & Associates
2:50 - 3:20	Questions and Answers - Institutional Heating Systems
3:20 - 3:30	Update on Geothermal Facilities Tour G. S. Budney, ETEC
3:30	Adjourn

THURSDAY, APRIL 17, 1980

8:00 A.M.	Charter bus arrives at Vacation Inn Travelodge
8:30	Bus leaves for tour
9:00 - 11:30	Tours of DOE Geothermal Test Facility (GTF) and MAGMA Electric Plant
12:00 Noon	Bus returns to Vacation Inn Travelodge

DIRECT HEAT APPLICATION PROJECTS

The use of geothermal energy for direct heat purposes by the private sector within the United States has been quite limited to date. However, there is a large potential market for thermal energy in such areas as industrial processing, agribusiness, and space/water heating of commercial and residential buildings. Technical and economic information is needed to assist in identifying prospective direct heat users and to match their energy needs to specific geothermal reservoirs. Technological uncertainties and associated economic risks can influence the user's perception of profitability to the point of limiting private investment in geothermal direct applications.

To stimulate development in the direct heat area, the Department of Energy, Division of Geothermal Energy, issued two Program Opportunity Notices (PON's). These solicitations are part of DOE's national geothermal energy program plan, which has as its goal the near-term commercialization by the private sector of hydrothermal resources. Encouragement is being given to the private sector by DOE cost-sharing a portion of the front-end financial risk in a limited number of demonstration projects.

The twenty-two projects summarized herein are direct results of the PON solicitations. These projects will provide (1) visible evidence of the profitability of various direct heat applications in a number of geographical regions, (2) technical, economic, institutional, and environmental data under field operating conditions that will facilitate decisions on the utilization of geothermal energy by prospective developers and users, and (3) demonstration of a variety of types of applications.

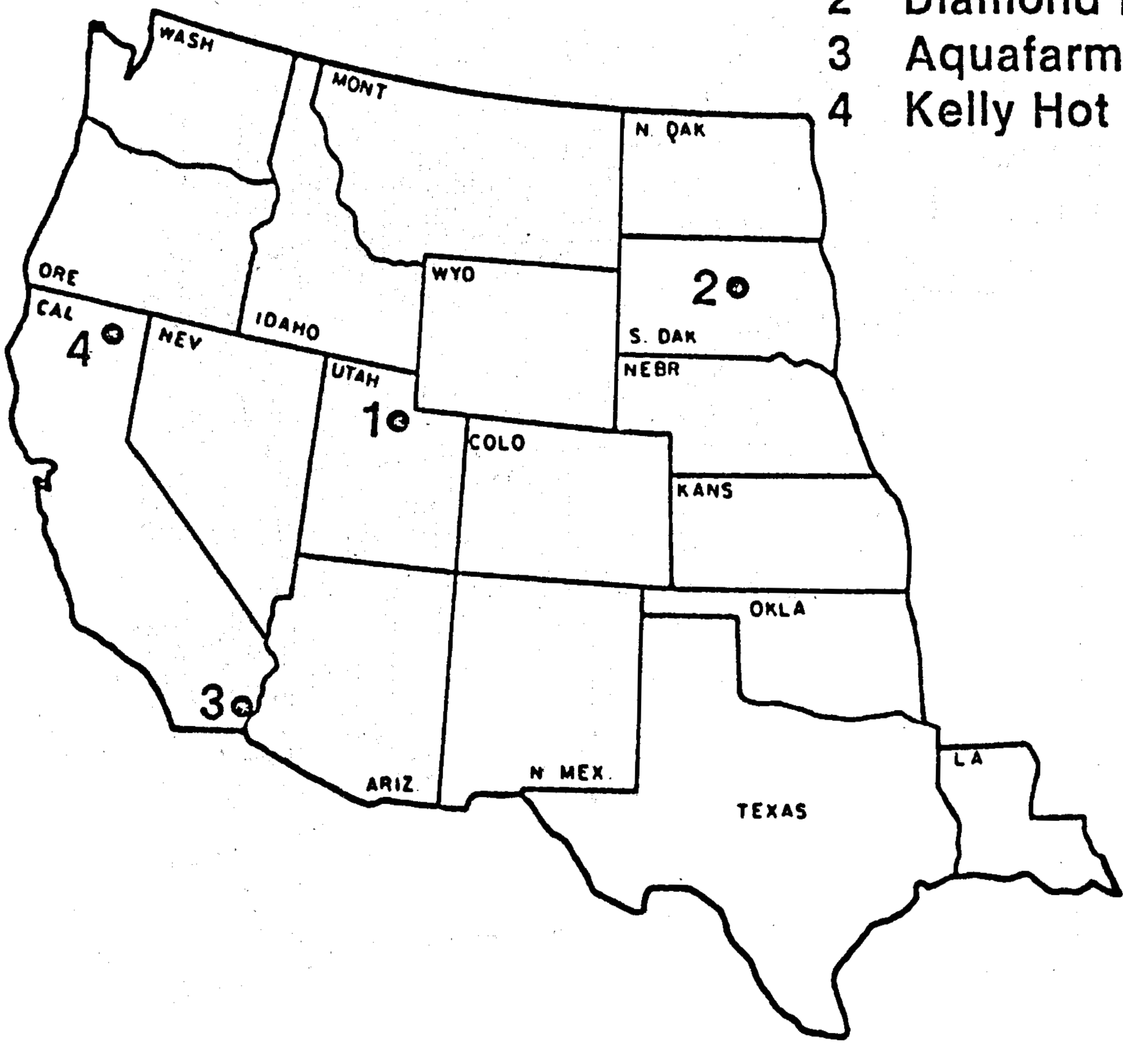
DOE PROJECT OFFICES

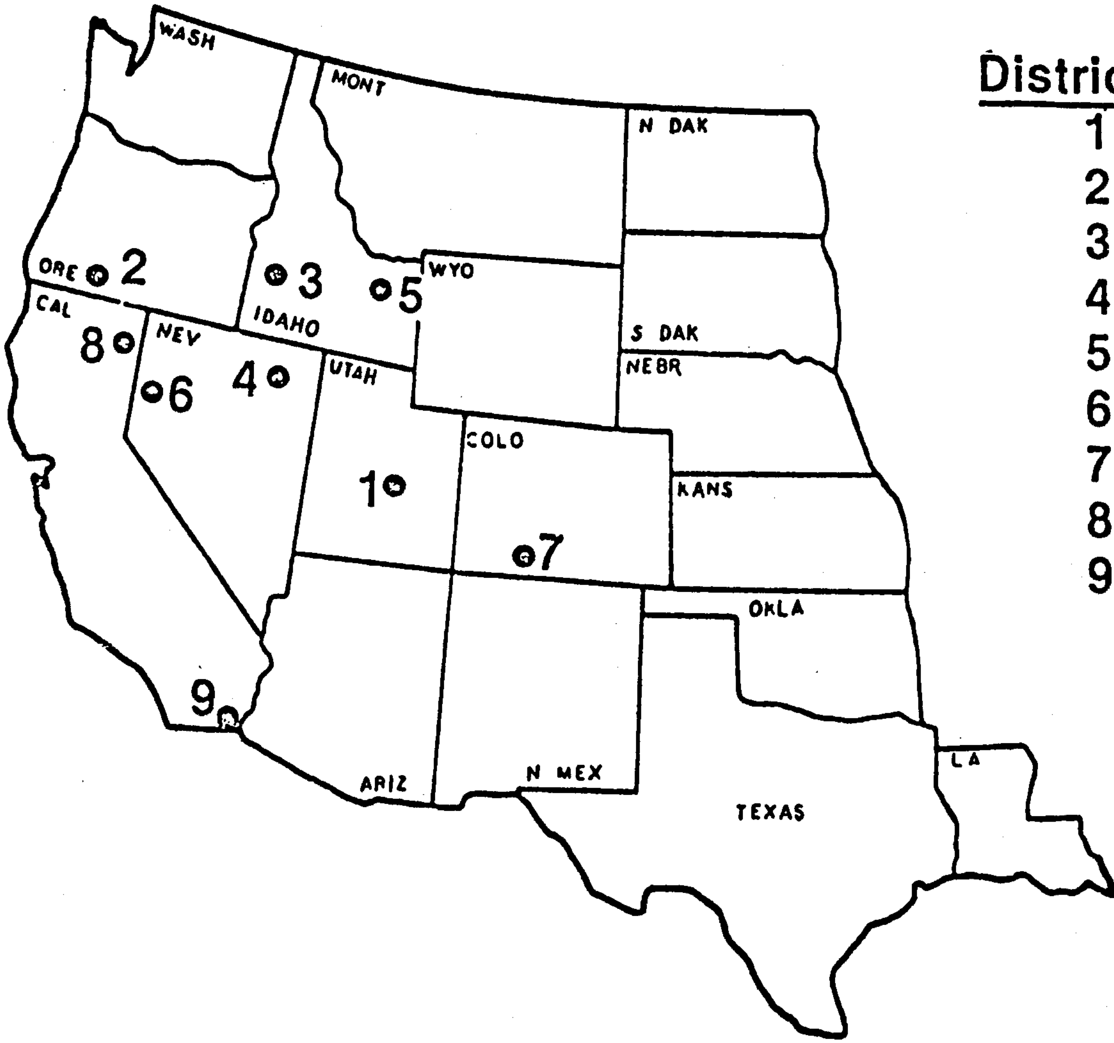
Three Department of Energy Operations Offices are responsible for the management of the direct heat application projects. The offices and their respective projects are:

OFFICE	PROJECTS
Idaho Operations Office 550 Second Street Idaho Falls, Idaho 83401 Contact: Mike Tucker Project Coordinator (208) 526-3180 Technical Support: Ed DiBello EG&G Idaho, Inc. Idaho Falls, ID 83401 (208) 526-9521	Boise Diamond Ring Ranch Elko Heating Madison County Monroe City Ore-Ida Pagosa Springs Philip Schools St. Mary's Hospital Utah Roses Utah State Prison Warm Springs State Hospital
Nevada Operations Office P.O. Box 14100 Las Vegas, Nevada 89114 Contact: Roland Marchand Chief, Engineering Branch (702) 734-3424	Navarro College T-H-S Hospital
San Francisco Operations Office 1333 Broadway Oakland, California 94612 Contact: Hilary Sullivan Program Coordinator (415) 273-7943 Technical Support: George Budney Project Manager Energy Technology Engineering Center Canoga Park, CA 91304 (213) 341-1000	Aquafarms International El Centro Holly Sugar Kelley Hot Springs Klamath County YMCA Klamath Falls District Moana, Reno Susanville

Agribusiness

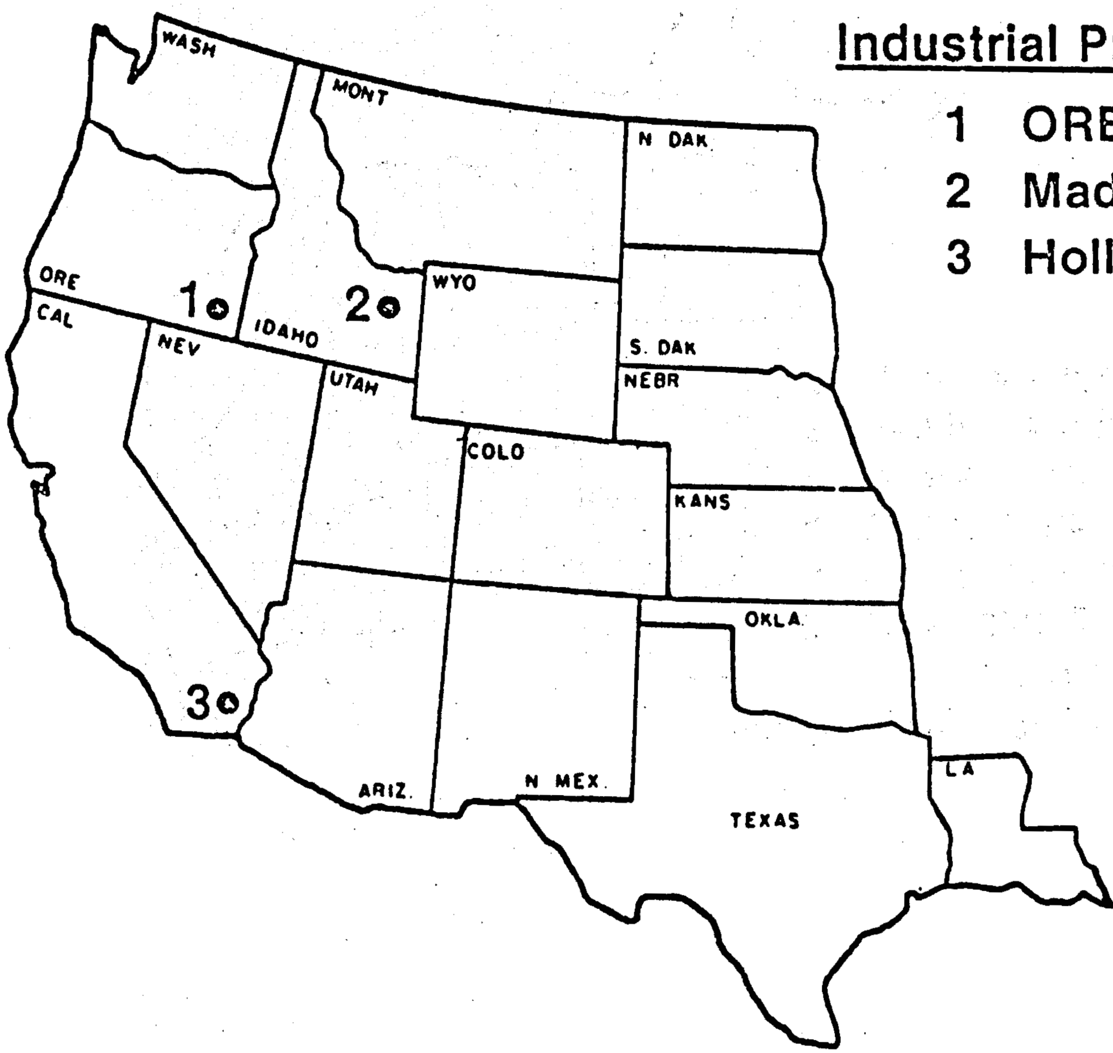
1 Utah Roses — Sandy, Utah
2 Diamond Ring Ranch — South Dakota
3 Aquafarms International — Mecca, Calif.
4 Kelly Hot Springs — Novato, California





District Heating Systems

1 Monroe City, Utah
2 Klamath Falls, Oregon
3 Boise, Idaho
4 Elko, Nevada
5 Madison County, Idaho
6 Reno, Nevada
7 Pagosa Springs, Colorado
8 Susanville, California
9 El Centro, California

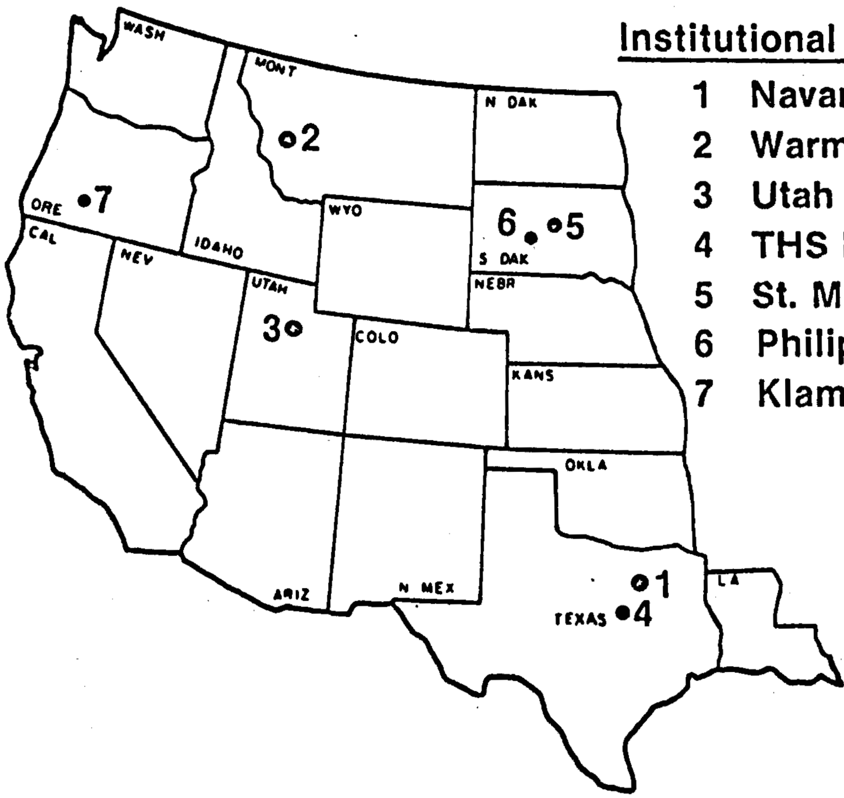


Industrial Process Sites

1 ORE-IDA — Ontario, Oregon

2 Madison County — Rexburg, Idaho

3 Holly Sugar — Brawley, California



Institutional Heating Systems

1 Navarro College & Hospital Corsicana, Texas
2 Warm Springs Hospital, Montana
3 Utah State Prison, Utah
4 THS Hospital, Marlin, Texas
5 St. Mary's Hospital, Pierre, South Dakota
6 Philip School, South Dakota
7 Klamath Falls, Oregon, YMCA

DIRECT HEAT APPLICATIONS

PROJECT DESCRIPTIONS

Aquafarms International, Inc.

(Input not received in time for printing)

Geothermal Power Corporation

KELLEY HOT SPRINGS GEOTHERMAL PROJECT

POST OFFICE BOX 1186
NOVATO, CALIFORNIA 94947
PHONE (415) 897-7833

Topical Report
GT 27041-1
March 21, 1980

KELLEY HOT SPRINGS AGRICULTURAL CENTER

Department of Energy Contract DE-AC03-79ET 27041
Phase I - Preliminary Design
October, 1979 - June, 1980

F. G. Metcalfe, Program Manager

A. B. Longyear, Principal Investigator

INTRODUCTION

This Topical Report summarizes the status of the Kelley Hot Springs Geothermal Project as it nears completion of Conceptual Design. The Conceptual Design will be completed and reviewed with DOE between the time of this Report and the El Centro Conference. Results of the review will be presented at the conference.

KELLEY HOT SPRINGS AGRICULTURAL CENTER

DOE PON DE-AC03-79 ET 27041

I. Project Description

A. Resource

The geothermal resource in the vicinity of Kelley Hot Springs has been estimated to be an extensive source of relatively clean hot water most applicable to direct energy utilization. Characteristics of the resource are summarized as follows:

The Warm Springs Valley of the Pit River is highlighted by Kelley Hot Springs, flowing at 96 C (205 F) at 320 gpm from a single orifice. The flow is at boiling for the elevation (4,360 feet). The region is part of the Modoc Plateau province. The Pit River Valley contains a thin veneer of stream-channel alluvium, flanked by terrace deposits and older and younger fan deposits. Beneath this are sedimentary and tuffacious beds of the Alturas Formation. Overlying these on higher hills are basalt flows of the Pliocene and Pleistocene Age. The principal fault of the region is the northwest-trending Likely Fault, which passes about one mile west of Kelley Hot Springs, and which appears to be a significant regional boundary.

Extensive exploration data include: Reconnaissance-level geologic mapping and gravity surveys, an aeromagnetic survey, at least 30 sq mi of electrical resistivity surveys, a reconnaissance-type telluric survey, a ground-noise and micro-earthquake survey, geochemical analyses, extensive temperature gradient surveys over a 15 sq mi area with 2.5-3 HFU across the area and a high of 20 HFU in certain holes.

Two exploration wells have been drilled. In 1969, Geothermal Resources International drilled to 3,200 feet, 1/4 mile south of the spring with a maximum temperature of 110 C (230 F) at

I. A. bottom. In 1974, Geothermal Power Corporation drilled to 3,396 feet, approximately 1-1/2 miles due east of the GRI #1 well. The maximum bottom hole temperature of 115 C (239 F) was measured in 1977 in KHS #1. The lithology of the two wells is similar.

The proven resource in this Project is a body of hot water at over 240 F in a porous reservoir between about 1,600 to 3,400 feet depth, covering an area of several square miles. A conservative estimate of the resource, assuming an areal extent of 4 sq mi, thickness of 2,000 ft, a reservoir temperature of 240 F, a reinjection temperature of 80 F, and a porosity of 20 percent (KHS #1 logs), will amount to heat in the fluid of 6.73×10^{16} calories. The reservoir within the drilled depth has sufficient reserve to supply the proposed plant, plus considerable additional development.

Kelley Hot Springs Water Chemistry

pH	7.9 - 8.6
Spec. Conductance	2.77 mmho
Salica	106 - 111 ppm
Ca	23 ppm
Na	231 - 244 ppm
K	6.2 - 6.8 ppm
HCO_3	28 - 50 ppm
CO_3	0.6 - 18 ppm
Cd	161 - 182 ppm
F	2.5 - 4.4 ppm
NO_3	0.9 - 1.8 ppm
B	3.9 - 7.9 ppm

Note: Range of samples collected by CA-DOG and USGS from 1957 to 1973.

B. Design

A 1,200 sow swine raising complex is being designed for an agricultural center to be located in the vicinity of Kelley Hot Springs, California. The center will be located adjacent to State Highway 299. The site is approximately 14 miles west of Alturas and four miles east of Canby in Modoc County. The swine raising is to be a totally confined operation for raising premium pork in

B. controlled environment facilities that utilize geothermal energy. The complex will have a feed mill for producing the various feed formulae required for the animals from breeding through gestation, farrowing, nursery, growing and finishing. The animals are shipped live by truck to slaughter in Modesto. A complete waste management facility will include manure collection from all raising areas, transport via a water flush to methane (biogas) generators, manure separation, settling ponds and disposition of the surplus agricultural quality water. The design is based upon the best commercial practices in confined swine raising in the U.S. today. The most unique feature of the facility is the utilization of geothermal hot water heat for space heating and process energy throughout the complex.

The complex is being planned so that expansion of swine raising capacity will be economically possible when the market may warrant. Through total confinement practices and the animal management criteria established for the design, the 1,200 sows will produce on the order of 25,900 marketable hogs per year at an average market weight of 228 pounds, for a total market live weight of approximately 5,900,000 pounds per year at steady state operations.

The facility layout at Conceptual Design is shown in Figure 1. A schematic of the principal flow is shown in Figure 2. The application is an adaptation of selected commercial confined swine raising complexes that are operating in the Midwest and Canada. Some of these facilities utilize fossil fuel fired hot water heating systems. The newborn and young piglets need temperatures in the range of 80 - 90 F, while the mother sow must be kept comfortable at 75 F. Some commercial facilities utilize electric radiation heaters for augmentation in the piglet area. For these areas, geothermal heated water radiant floor heating is planned in this Project.

C. System Economics

The complex will be 100 percent geothermally heated, with hot water used for direct space heating through heat exchangers and as radiant piping in the floor slabs in swine farrowing and nursery buildings. Preliminary information, currently undergoing review, indicates an

I. C. annual energy load represented by geothermal at 8.1 X 10^{10} BTU/yr and a peak use of 18,400,000 BTU/hr. This represents a replacement of 673,000 gal/yr (or 16,000 bbl/yr) of #6 fuel oil.

In that this design is at the conceptual level as of the time of writing this Report, the payback period is not at hand. The Project has been based upon an extension of the work conducted for the Mountain Home Geothermal Project, a previous DOE PRDA. In that effort, an economic analysis of a 7,200 sow complex, including slaughter facility, indicated a payback period on the order of 3+ years for owner's share of the capital (25 percent of capital).

II. Status

A. Technical Scope

As discussed earlier, it is proposed to build and operate a 1,200 sow confined swine production complex using the available geothermal resource for all heating requirements. Phase I takes the Project through the Conceptual Planning and Preliminary Design levels. There have been no changes in the technical scope other than delaying well rework into the Phase II construction effort. Geologic expert opinion indicates that more complete reservoir assessment work will result from the drilling and testing of the supply well as proposed for Phase II. It is the opinion of said expert that the data in hand is adequate to complete the Phase II well siting and justification report during Phase I.

B. Schedule

The Phase I effort is on schedule with the exception of the delayed well rework described above. Major milestones have been met with such items as the Draft Environmental Report , Criteria Development, Trade Studies and Conceptual Design now completed. Remaining to be completed in the next few months are Preliminary Design, Economic Analysis and preparation of the Phase II proposal.

It is expected that with Phase II funding available during the summer of 1980, the resource will be confirmed with production well drilling, casing and testing being performed during late summer and early fall, 1980. Sitework, utilities and foundation work could proceed until mid-December, 1980, when the first fabricated metal buildings could be erected; and interior work go on under protection during the winter. The balance of the construction could start up in the spring of 1980 with completion by late 1981.

The system could start up in the fall of 1981 starting with swine production beginning in the Breeding and Gestation areas initially. During the winter of 1982, the first of the hogs would be processed through Growing and Finishing areas and be ready for market.

The only schedule slippage, that of a delay to Phase II of well rework, has been discussed earlier. No other slippages are expected in Phase I. However, a delay by the DOE in awarding its Phase II

II. B. contract into the fall of 1980 or later could throw the construction schedule off considerably. Since the contract may stipulate the proving out of the first development well before sitework and construction could begin, and since this work could not be initiated during the severe winters experienced in Modoc County, the whole schedule might slip as much as 6 months or more.

C. Cost

The Phase I contract has a DOE share of $473,303 and a contractor share of $41,426. There is not expected to be any over or under run at the end of the contract. Certain overruns in well rework and in an unexpected archeological survey have been taken care of by reduction of other contract activities.

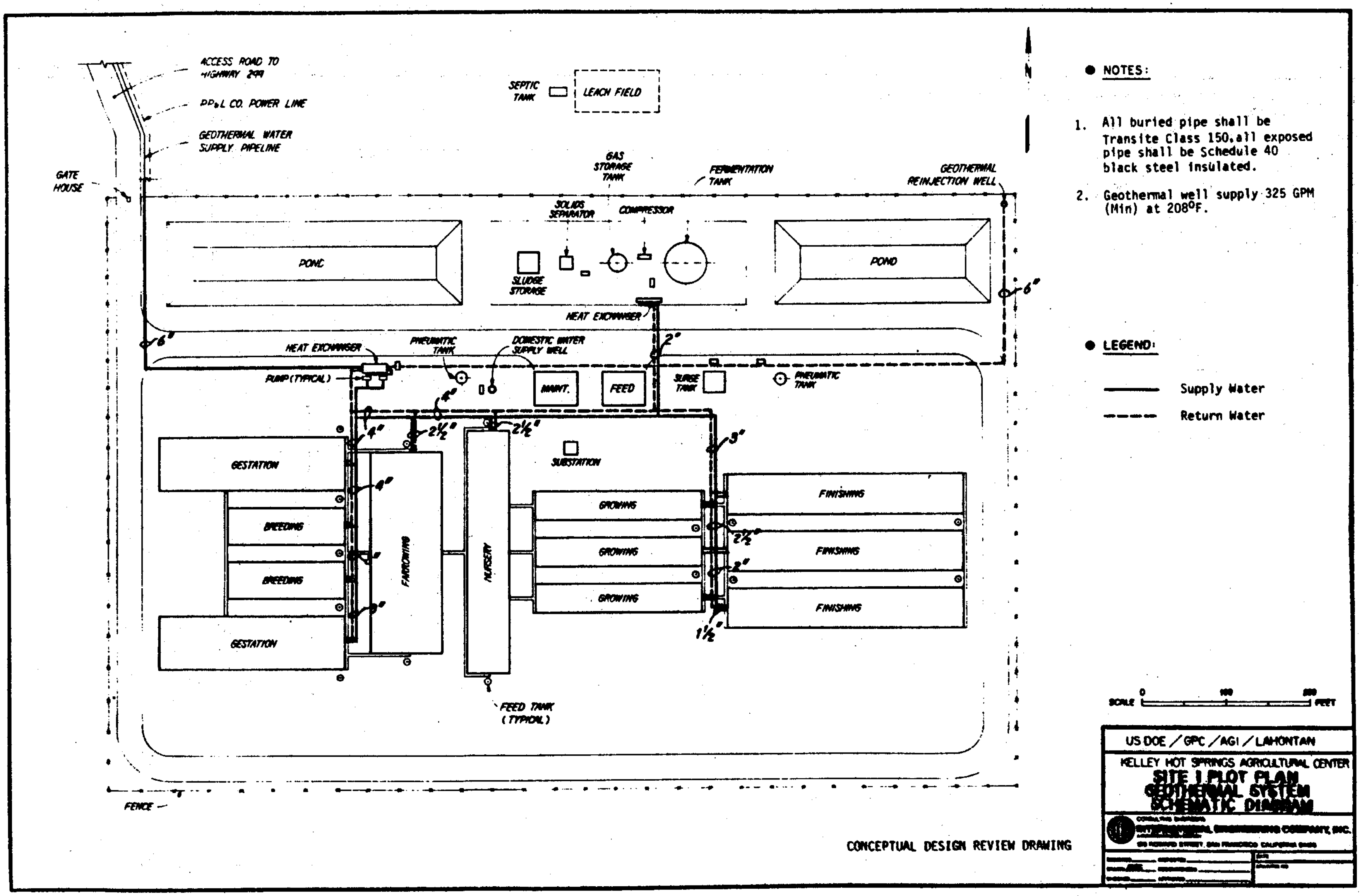


Figure 1 - Kelley Hot Spring Agricultural Center Facility Layout

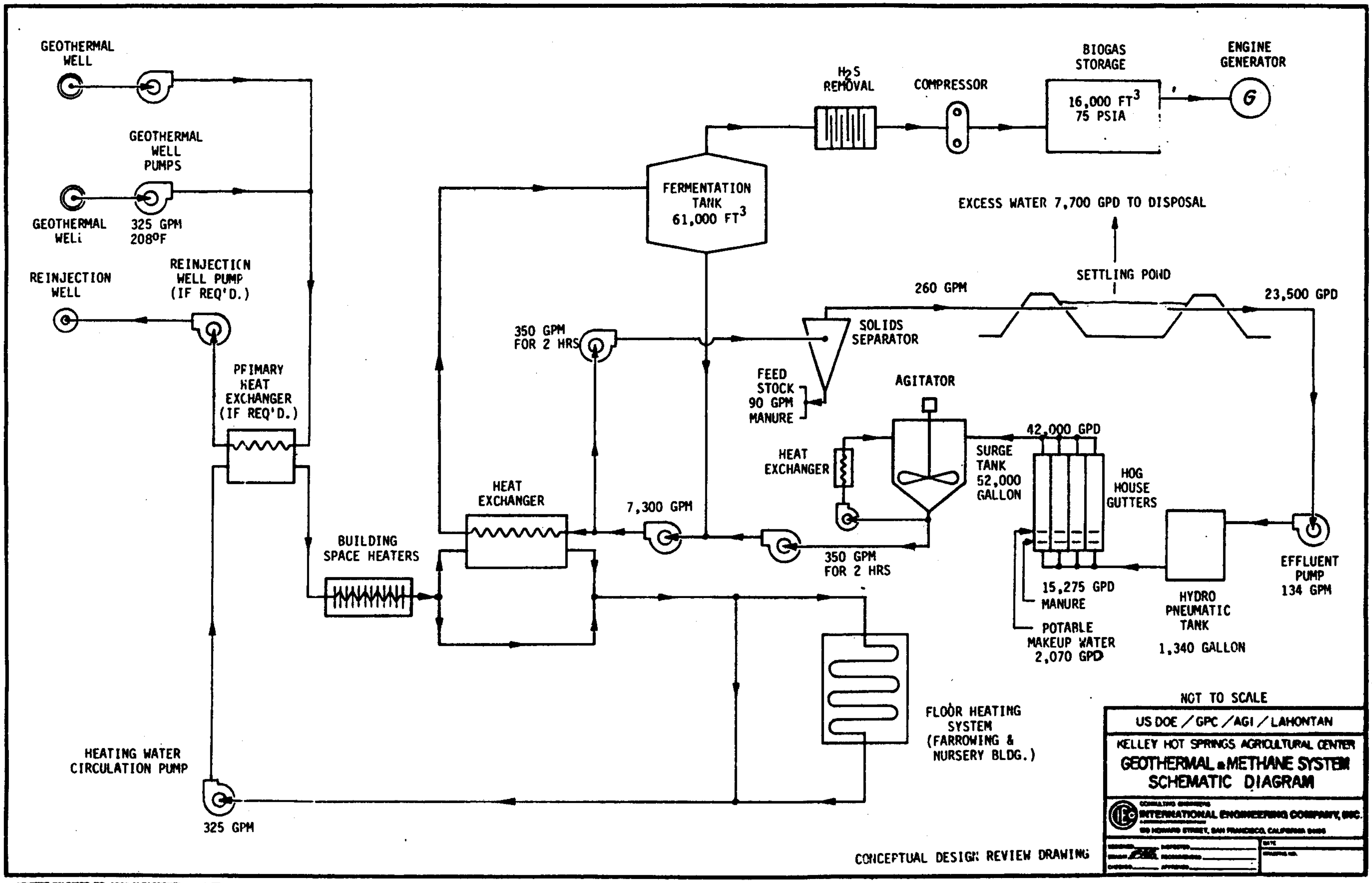


Figure 2 - Kelley Hot Spring Agricultural Center Flow Schematic

UTAH ROSES
GEOTHERMAL PROJECT
SANDY, UTAH

(METROPOLITAN SALT LAKE CITY)

OWNER & PROGRAM MANAGER - RALPH M. WRIGHT

ENGINEERS - ENERGY SERVICES, INC., IDAHO FALLS, ID

AUTHORS: DR. JAY F. KUNZE AND RAY W. GOULD ENERGY SERVICES INC

BACKGROUND - The Utah Roses 6-acre greenhouse facility, in a suburb of Salt Lake City (Figure 1), used $130,000 of hydrocarbon fuels this winter. Its location has served as a pilot project for the entire Salt Lake Valley. Success on this project should determine that geothermal space heating is economically practical for the entire city.

1. Project Description

Resource

A well to a depth of 5,008 feet (Figure 2) was completed in December, 1979, and a casing liner hung in March. Bottom hole temperatures are 160°F, and sustained flow rates of 280 gallons per minute have been determined to be practical from a pump setting depth of 750 feet.

The well is artesian (free flowing). The waters have about 2,800 ppm dissolved solids, mostly sodium and chloride ions. There is no significant toxicity in trace elements, and radioactivity seems minimal and within drinking water standards.

Design

The heating system for the 250,000 sq. ft. of greenhouse will not be in the final design stage until remedial action on the well is completed. This will consist of perforating the liner in order to increase flow, without adversely affecting temperature. Once the ultimate capability of the well in terms of flow and temperature is determined, then work will proceed on the design of the heating system. Pipelines for the project will be minimal, because the well head is only 75 feet from the greenhouse complex west end.

System Economics

Even if the present flow rate capability of 280 gpm and 120°F temperature at the wellhead cannot be increased, it appears quite practical to strip 35°F from the geothermal water for heat into the greenhouse. This would produce 5 million Btu per hour, enough to provide the heating needs of the entire greenhouse down to 40°F. This result could provide about 40% of the annual heating needs, which presently total about $130,000 per year. Current gas rates are 19 cents per therm ($1.90/million Btu), but threaten to increase significantly in the near future. For instance, the neighboring gas company that serves Idaho charges about $5.00 per million Btu, not much different from the cost of heating oil.

The total project cost is expected to be $800,000 (half of which has been spent to date). With average yearly fuel savings over the next 10 years of approximately $100,000 per year, the minimum expectation from this project, it appears that this first attempt at harnessing geothermal energy in the center of metropolitan Salt Lake City is economically justifiable, with an 8 year minimum payback.

The final result on the ability of the well to produce hotter water at the surface, and higher flow rates is not known as of the date of this writing. However, a second well could be drilled to produce similar flows, adding 50% to the cost of the project, but increasing the annual energy savings by about 100%. The payback period would then be 6 years.

II. STATUS

Technical Scope

The size is unchanged from the inception of the project. The temperature (120°F) that has been obtained at the wellhead to date is the minimum expectation originally considered as economically feasible. Flow rates are less than expected, but the perforating of the liner of the well has not yet been done, and this action should significantly increase the flow. The increased flow should also result in less temperature loss from the producing formation to the wellhead.

Insulated pump columns are being considered to further reduce this loss.

However, the extraction of the heat for use in the greenhouse may involve different schemes than originally planned. Pipes laying on the soil to maintain soil temperature as well as providing some space heating may be the most cost effective method of using this heat for the industrial process of maximizing rose production. Additional wells were suggested as possibilities in the original plan, and these will receive serious consideration, if production rates from this well cannot be significantly increased.

Schedule

The original schedule of having geothermal heat into the greenhouse by the fall of 1980 still is the planned schedule, and should be acheived.

Major milestones have been as follows:

February, 1979 - Environmental Report Completed.

July, 1979 - Resource report completed, including pump testing of an 800 foot well 150 yards away, that produced 94°F water from a depth of 300 feet (total well depth was 800 feet, but temperature didn't vary from 300 feet down).

November 24 - Drill Rig moved on to site.

December 9 - Well completed to 5,008 feet and drill rig dismissed.

March 4, 1980 - Workover rig brought in to clean out well and set liner from 2,100 feet to 3,900 feet.

March 7 - Liner hung. Workover rig dismissed.

Total cost of 5,008 foot well, approximately $330,000.

Principal Accomplishment

Useable hot water has been found in general drilling near the Wasatch Fault in the interior of metropolitan Salt Lake City. The site has nothing special in terms of other major faults, geological anomalies, or any encouraging geophysical evidence. Thus, one can assume that similar wells could be successfully drilled all along the Wasatch Front Fault. Costs of the well were kept unusually low, for a 5,008 foot well. It would appear that future target drilling depths could effectively be limited to 4,000 feet, thus further reducing well costs. The current well cost was a bit more than the original budget of $285,000 for a 3,000 foot well, but this well was drilled to 5,008 foot in search of hotter water. All other costs are well within budget.

Whether or not a re-injection well is needed, or whether the adjacent Galena Canal can be used for the discharge water has yet to be determined. Project personnel believe that the Galena Canal, which ends 1-½ miles downstream in a slough at a mining tails area, can accept the discharge water in an environmentally acceptable manner. However, permission for such discharges must be granted by the State and the EPA.

III. LESSONS LEARNED

Deep wells for geothermal direct use applications can be drilled effectively and relatively inexpensively, even in difficult alluvial formations. The project has already proven its minimum economic feasibility, and should provide the emeptus to open the entire Salt Lake City Valley to the utilization of geothermal energy for space heating.

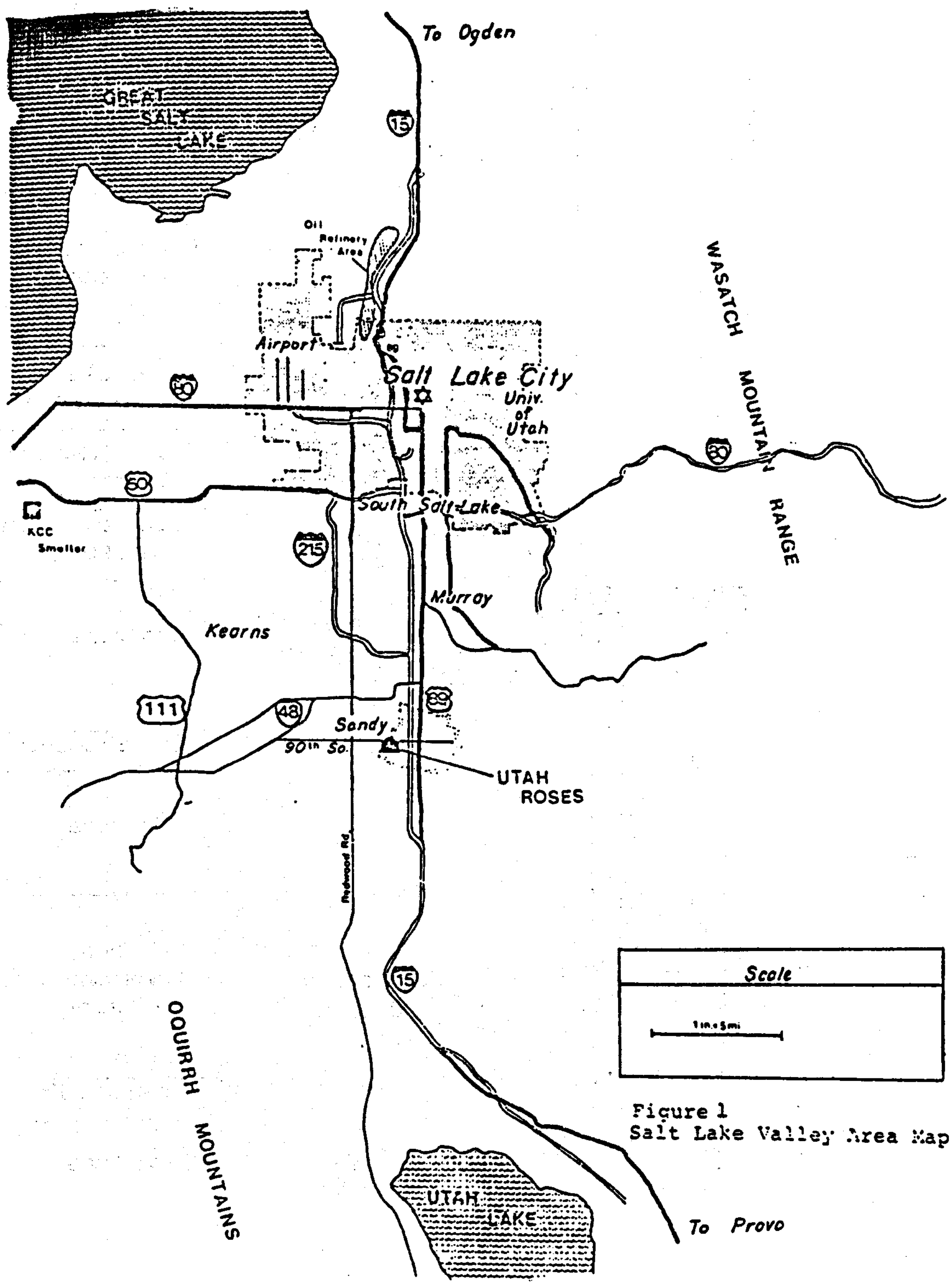
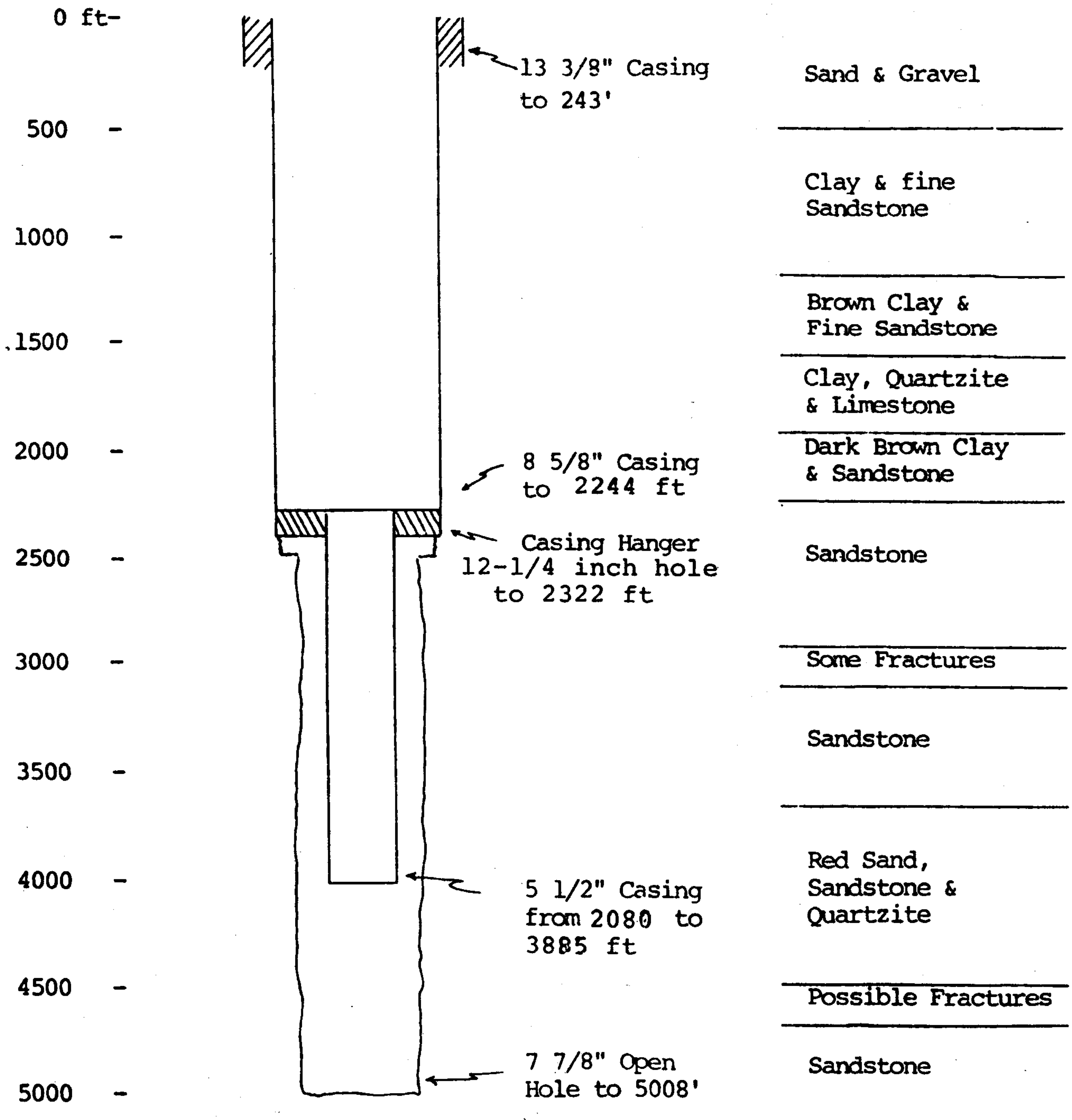


Figure 1
Salt Lake Valley Area Map

UTAH ROSES

WELL PROFILE AND LITHOLOGY



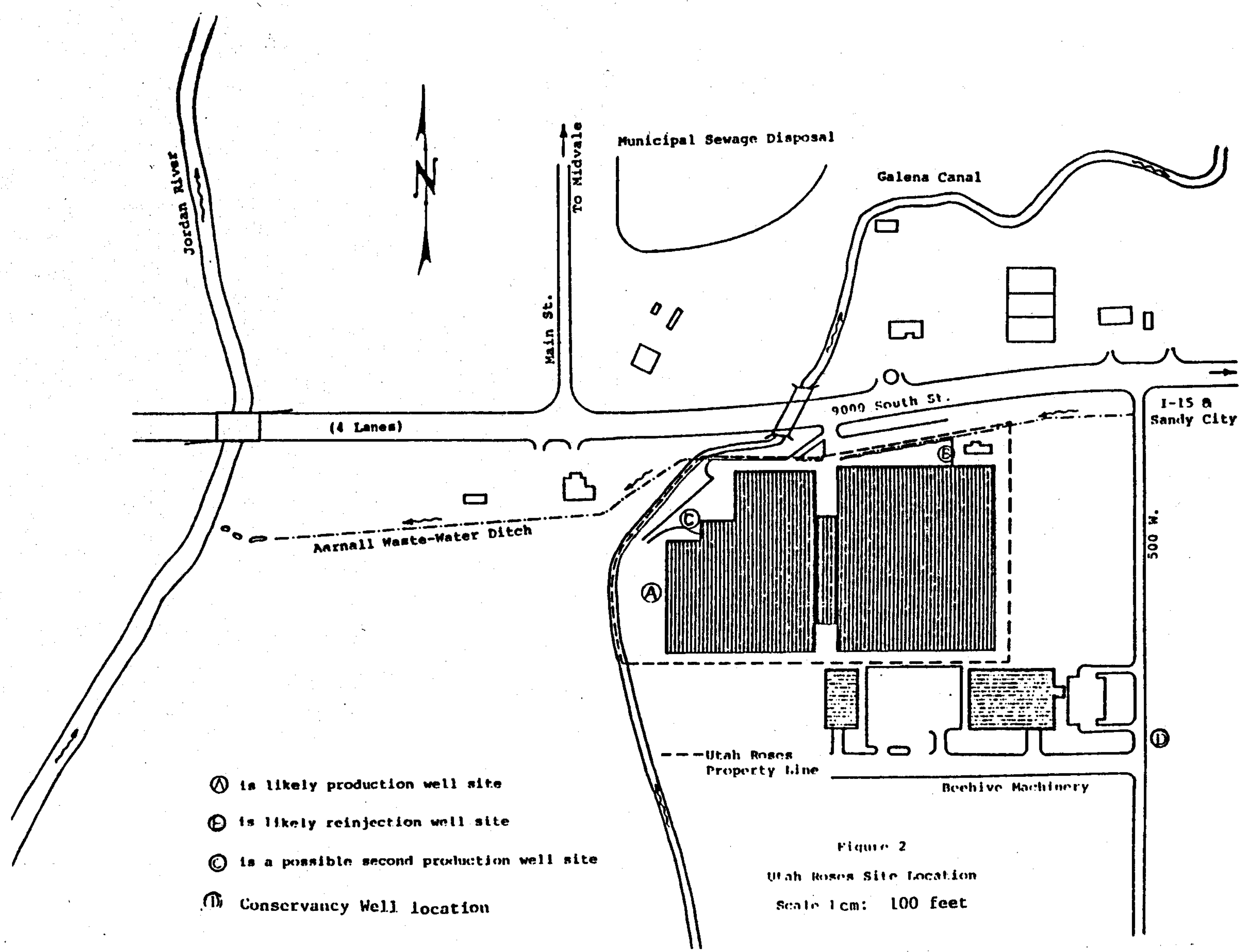


Figure 2
Utah Roses Site Location
Scale 1 cm: 100 feet

DIRECT UTILIZATION OF GEOTHERMAL ENERGY IN WESTERN SOUTH DAKOTA AGRIBUSINESS

Geothermal Direct Heat Application Program
Semi-Annual Review Meeting
El Centro, California

April 15-17, 1980

Dr. Stanley M. Howard
Project Manager
South Dakota School of Mines and Technology
Rapid City, SD

Mr. Thomas Zeller
Design Engineer
RE/SPEC, Inc.
Rapid City, SD

Mr. Gene Armstrong
Owner
Diamond Ring Ranch
Midland, SD

I. PROJECT DESCRIPTION

The project site is the Diamond Ring Ranch located approximately 50 miles west of the capitol of South Dakota, Pierre. The ranch is one of the largest in the region. Approximately half of land is used for grazing while the other half is under cultivation. Unirrigated wheat is the major crop. Irrigated corn and dry land sorgum provides the major feed source for a 4000-cattle feed lot operation. The geothermal well supplying water for this demonstration project was completed in 1959 for the primary purpose of providing livestock water. However, it is also the best water available for domestic purposes. A small part of the well discharge is used for irrigation. With the completion of the geothermal heating system, the water now provides space heating for numerous structures and heat for grain drying. Discharge water is contained in a reservoir system also used for natural run-off collection.

A. RESOURCE

The geothermal resource is the Madison Aquifer which is composed of three lithologic units: the Lodgepole; the Mission Canyon and the Charles.

1. Location - The Madison extends under the western half of South Dakota and into the bordering states of Wyoming, Montana, and North Dakota. The project site is near the eastern boundary of the Madison.

2. Depth - The Madison is generally several thousand feet beneath the surface except near the Black Hills where it outcrops. At the project site the well depth is 4112 feet.

3. Temperature - Figure 1 shows an isothermal map of the Madison in western South Dakota. Temperatures range up to 170°F. The temperature at the project site is 152°F.

4. Flow Rate - Most Madison wells in South Dakota are naturally flowing. Flow rates of 1000 gpm are not uncommon for the lower-temperature wells. The hotter wells generally flow at several hundred gpm. The Diamond Ring Ranch well flows at 170 gpm.

5. Fluid Chemistry - Table 1 gives the range in water analysis for Madison waters in South Dakota as well as the analysis at the Diamond Ring Ranch. The water exhibits minor scaling in

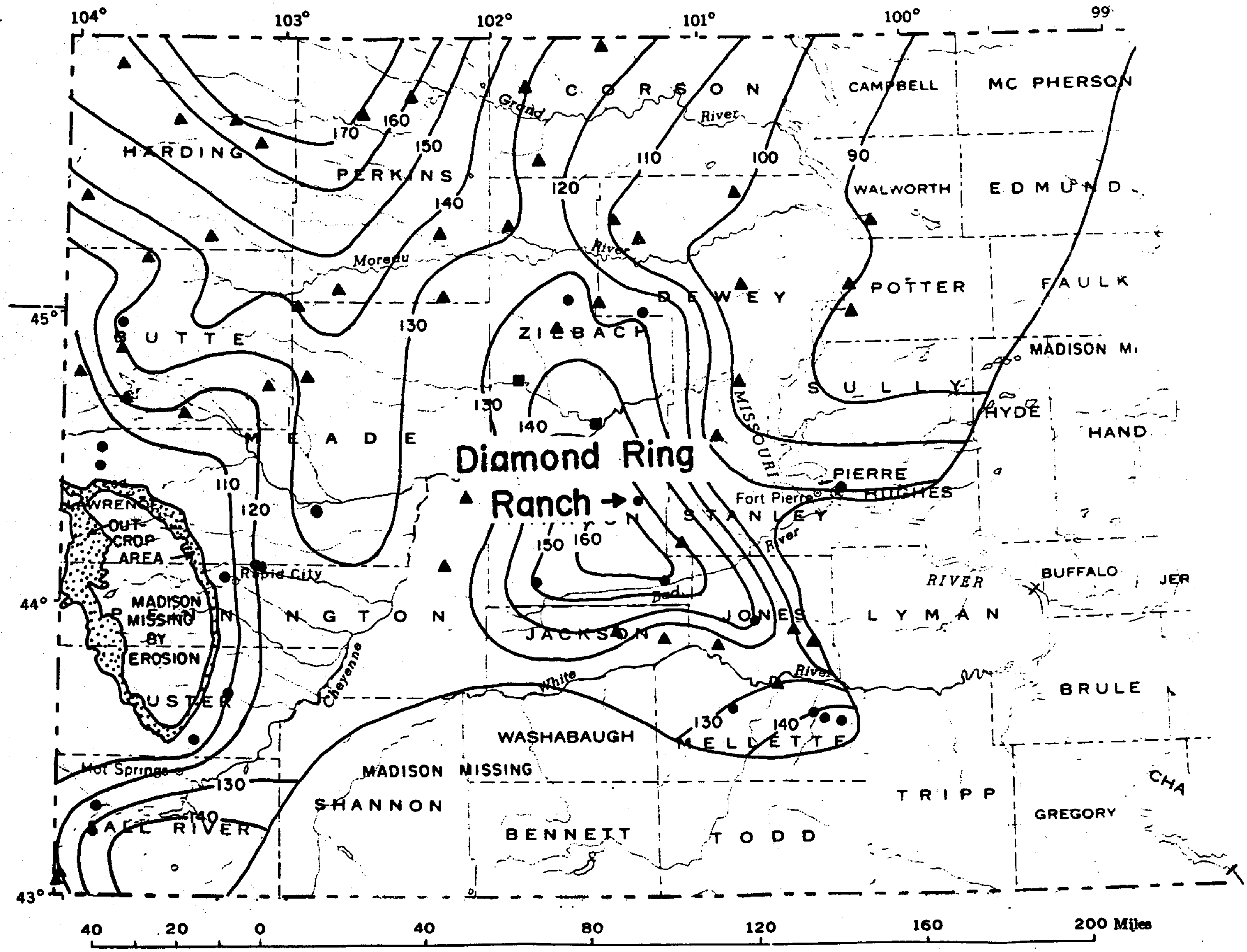


Figure 1 - Isothermal Map of Western South Dakota (°F)

Table 1 - Water Analysis

SPECIES	CONCENTRATION (PPM)
AlK ($CaCO_3$)	950
HCO_3^-	126
$SO_4^=$	1087
Cl^-	185
F^-	2.4
$PO_4^=$	0.07
SiO_2	42
Ca^{++}	381
Mg^{++}	79
Na^+	85
K^+	15
Fe (total)	0.14
Mn^{++}	0.40
B	0.43
TDS	2066
pH	6.9
Temp(°C)	64
$S^=$	0.20

piping before exposure to air. The scale is a fine dispersion of iron pyrite which do not adhere to PVC piping. The quantity of this scale is roughly estimated to be on the order of several pounds per week at full flow.

The results of a lengthy coupon corrosion testing program are summarized in Table 2. Three-point stress corrosion cracking specimans stressed at the outer fiber to 80 percent of the yield stress showed no evidence of cracking after sixty days of exposure.

B. DESIGN

The primary difference between this project and many district heating systems is that the heat available from the geothermal well exceeds the peak heating requirements of all buildings requiring space heating. Consequently, there was never any serious consideration given to any system which could not meet peak demand.

A major design consideration was simplicity since the Diamond Ring Ranch is fifty miles from the nearest city where competent maintenance and repair service personnel could be found. A second major objective was to build a system which could withstand prolonged electrical power outages which are common during severe winter storms.

1. Piping Layout - The geothermal well is approximately 4000 feet from the grain dryer and the structures to be heated. Figure 2 shows the pipeline layout. A six-inch fiberglass reinforced PVC pipeline with slip joints was placed from the well to the grain dryer. At that point the line branches into two four-inch lines; one runs into the grain dryer building and one to the shop. In the grain dryer, the geothermal water flows through an Alfa-Laval plate-type, water-to-water, heat exchanger (model P-31) with 58 plates. The water is then discharged into a ravine and runs into a large stock dam. The flow from the well is gravity feed and is controlled with a pinch valve at the discharge point.

In the shop, the geothermal water flows through the same model heat exchanger as used in the grain dryer. The only difference is that the shop exchanger has 54 plates. The discharge from the shop runs to a tee where it can either be discharged into a ravine leading to a collection reservoir or allowed to flow through a looped two-inch PVC line cemented into the floor of a guest house and garage which are adjacent to the owner's home.

A significant amount (up to 25 gpm) of the raw geothermal water leaving the shop heat exchanger is pumped to the livestock watering system from a point several feet downstream from the shop exchanger.

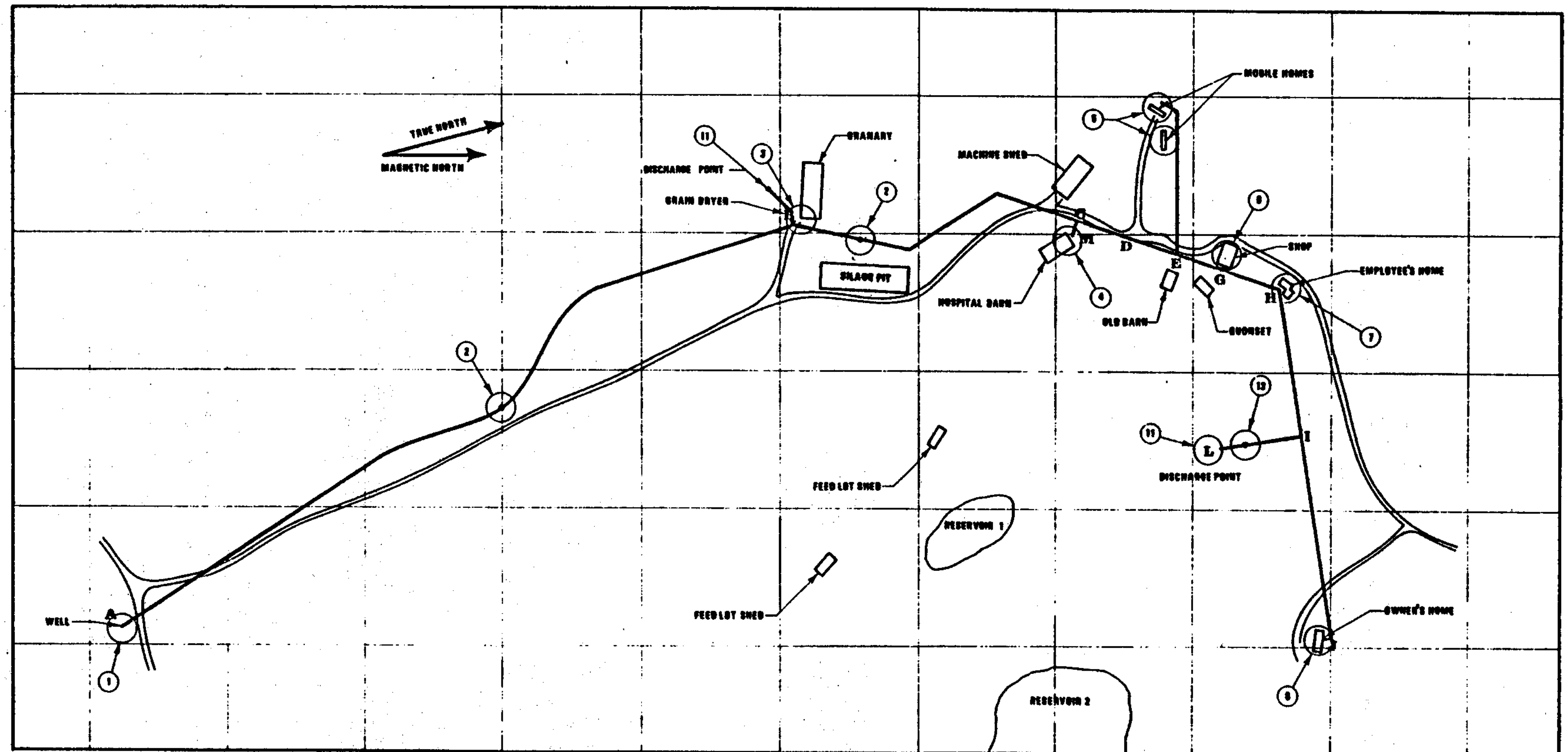


Figure 2 - Diamond Ring Ranch

Table 2 - Weight Loss Results for the Coupon Tests
Corrosion Rate in μm/yr

	MADISON									INYAN KARA	
	EDGEMONT			PHILIP			DIA. RING			CAPITOL	
	DAYS			DAYS			DAYS			70 DAYS	
MATERIAL	149	308	457	148	460	608	97	317	414	A.R.	POLISHED
C61300	2.54	3.81	1.27	6.10	4.06	7.11	9.91	10.7	9.91	43.9	43.9
C61300 (welded)	3.81	4.06	2.29	10.9	4.32	6.10	15.0	11.9	12.2	43.9	43.9
C95800	3.30	4.06	1.02	13.0	8.89	12.2	8.38	4.57	14.5	3.05	49.3
C95800 (annealed)	9.14	3.81	3.56	-	-	-	14.7	8.13	8.89	-	-
C95800 (welded)	3.81	4.06	2.79	15.2	8.89	11.68	13.2	6.10	9.14	50.3	28.4
Copper	6.10	6.35	4.06	3.30	3.81	4.32	86.9	113.	82.0	33.3	31.5
C44300	10.92	10.67	10.4	3.05	1.27	2.29	18.8	9.4	14.0	1.27	2.03
C71500	11.43	9.91	8.38	8.13	7.11	7.62	37.1	45.2	11.9*	12.7	21.3
Monel 400	30.23	17.0	18.3	10.2	6.10	5.84	10.7	19.3	24.1	0.18	4.83
SS304	0.36	0.13	0.23	0.48	0.10	0.10	3.81	16.8	8.89	0.43	0.18
SS316	0.20	0.13	0.25	0.64	0.10	0.10	4.32	2.79	3.56	0.76	0.13
Carbon Steel	386.	213.	300.	120.	447.	338.	389.	343.	401.	1206.	-
Al3003	-	-	†	112.	-	74	82.3	-	†	-	-
Ti	0.48	-	0.11	-	0.00	0.02	0.00	0.89	0.00	0.00	-

* A black coating could not be removed resulting in lower weight loss and corrosion rate.

† Destroyed

2. Geothermal Path - A water-propylene glycol mixture is circulated by pump through the plate-type exchanger at the grain dryer and a large water-to-air radiator is drawn through the radiator by a tractor-driven fan in the grain dryer. The water-glycol mixture prevents the radiator fluid from freezing.

At the shop, water is circulated through the plate-type exchanger and through two heating loops. One loop runs to the hospital barn, the mobile homes, and the shop. The second loop runs to the employee's home and the owner's home. Heat from the recirculated water is used to heat air in all the structures. In the hospital barn and shop, fan coil units are used. In the homes, water-to-air exchangers were placed in existing plenums of the forced-air heating systems. The pre-existing heating systems in the homes were left in tact for back-up heating.

3. Unique Features - The corrosiveness of the geothermal water required the use of stainless steel 316 for all exchanger surfaces in contact with the geothermal water. Consideration was given to the direct-use of the geothermal water in water-to air exchangers, but the cost of such units and associated control problems made that approach unacceptable in all cases except at the grain dryer where the cost was comparable to the design finally accepted. At the grain dryer, the direct geothermal-to-air approach had obvious advantages with respect to freezing protection, but was rejected because of the eventual prospect of corrosion failure resulting in very costly water damage to grain in the dryer.

C. SYSTEM ECONOMICS

The system construction was completed during the last quarter of 1979. Since that time minor adjustments and revisions have been made. Full-scale operation and monitoring will be performed during the 1980-81 heating season. Therefore, all system economics are based on estimated demand and design performance.

The most important fluctuating factor in determining system economics is the extent of grain dryer use. This can vary widely with climatological factors which affect crop yields and moisture content. Also, management decisions about crop type and use can affect the extent of dryer use. Consequently, the following analysis is performed as a function of grain dryer use.

1. Fossil Fuel Requirements - Table 3 shows the space heating demands replaced by the geothermal system, the type of heating replaced, and the heat from fossil fuel required to satisfy these demands. The peak hourly fossil fuel requirement is 1.351×10^6 BTU/hr. which translates into an average annual demand of 3.55×10^9 BTU. This value is added to the grain dryer

TABLE 3 - HEAT DEMANDS FOR SPACE HEATING

STRUCTURE	DEMAND ($BTU \times 10^3/yr$)	REPLACED	FOSSIL FUEL ($BTU \times 10^3/yr$)
Owners Home	180	Elect-H.P.	450
Employee Home	100	Propane	125
Mobile Home -1	80	Propane	100
Mobile Home -2	80	Propane	100
Hospital Barn	110	Propane	138
Shop	110	Propane	138
Bunk House	100	Elect. Resist.	300
		TOTAL	1,351

Average Annual Demand = 3.55×10^9 BTU/yr

TABLE 4 - TOTAL ANNUAL HEAT DEMANDS AND FOSSIL FUEL REPLACEMENT AS A FUNCTION OF GRAIN DRYER USE

MONTHS OF GRAIN DRYER USE PER ANNUM	DEMANDS (million BTU/yr)			FOSSIL FUEL (bbl/yr)
	Space Heat	Grain Dryer	Total	
0	3,550	0	3,550	634
1	3,550	1,440	4,990	891
2	3,550	2,880	6,430	1,148
3	3,550	4,320	7,870	1,405
4	3,550	5,760	9,310	1,662
5	3,550	7,200	10,750	1,920

demand in Table 4 and the total converted to equivalent barrels of oil replaced by the geothermal system.

2. Percent Geothermal - All of the space heating requirements are designed to be met by the geothermal system. The air for grain drying is heated by geothermal energy only.

3. Payback Period - The payback period varies greatly with the extent of grain dryer use. It is also affected by the following:

- Method of financing
- Interest rate of financing (i)
- Initial energy cost savings
- Rate of inflation of energy cost (e)
- Rate of return required on invested funds (r)
- Capital outlay
- Maintenance and operation cost

For the following analysis, 100 percent financing was assumed and recovered in equal year-end payments at interest rate i. Various interest rates were selected for i, e, and r. The initial energy cost savings was based on the assumed average cost of \$3.50 per 10^6 CTU's for replaced energy. This value is probably somewhat low. A higher value would make geothermal more favorable. Maintenance and operation costs were assumed to be equal to the corresponding costs for conventional systems. Therefore, they do not affect the payback period.

Three different values were used for capital outlay. In the first case a value of \$256 K was used. This is the actual outlay for the Diamond Ring Ranch Project. However, it does not include: (1) the sunk cost of the well which was originally drilled for stock watering; and (2) the cost of equipment required regardless of heat source (air ducts, thermostats, grain dryer, etc.). The second case is the same as the first except the capital outlay was reduced by \$64 K to show the impact of shortening the very long pipeline from the well to the ranch structures (4000 feet). Therefore, the resulting \$190 K capital outlay represents the payback for a similar project with a well drilled for stock watering close to the ranch structures.

The third case is for \$430 K. This amount includes \$240 K for a new well but assumes close proximately to the ranch structures as in the second case.

The results of the payoff calculations are shown in Table 5. The quantities in parentheses show the present-value losses for a 20-year project. The table shows the pronounced influence of grain dryer use on payback. Interestingly, the interest and inflation rates selected have a smaller impact. In fact, the first three rate choices yield nearly identical results. The second and third set illustrates the relative insensitivity of pay off time to rates. Set four is most unfavorable consisting of the rather unlikely case of finance rates exceeding the energy inflation rate. Of course, the capital outlay has a major influence on payback time.

II. STATUS

The scope of this project and the original schedule has changed little.

A. TECHNICAL SCOPE

The major changes are as listed below.

i) Originally feedlot sheds were to be heated by passing raw geothermal water through PVC pipes buried in a concrete floor which was to be placed as part of the project. Since the sheds were open on one side, the benefit of such heating was not found to justify the cost. Therefore the shed heating portion of the project was eliminated. In lieu of the sheds, a new bunkhouse and garage structure was built that incorporated the same technology.

ii) The second major design change was the use of two isolation heat exchangers. Originally, only one in the shop was planned, but economic analysis showed considerable cost reduction was possible by incorporating a second isolation exchanger at the grain dryer. The primary savings resulted from the reduction of the supply pipeline size from the grain dryer to the shop and elimination of the recirculating lines from the shop for the grain dryer.

B. SCHEDULE

The original schedule was maintained quite well up to the awarding of the construction contract. The bids received were approximately 100 percent above the budget. This required the design modifications cited above which brought the bids to 60 percent above budget. Additional delays were required to obtain a revised contract with the U.S. Department of Energy. Total delay caused by the higher-than-expected bids was approximately three months. However, construction was completed before the 1979-80 winter and initial operation has been possible during the 1979-80

TABLE 5 - PAYBACK PERIOD IN YEARS

Grain Dryer Use (mo/yr)	Interest and Inflation Rate (%)			
	i = 18	20	8	10
	e = 24	22	10	8
	r = 18	24	12	12
Case I: $256K (no well)				
0	(11)	(98)	(78)	(127)
1	14.4	(15)	19.7	(59)
2	11.0	14.5	13.8	18.5
3	9.0	11.1	10.7	13.5
4	7.6	9.0	8.8	10.6
Case II: $190K (no well-shorter lines)				
0	16.9	(42)	(28)	(69)
1	11.5	15.6	14.6	(1)
2	8.7	10.7	10.3	12.8
3	7.0	8.2	8.0	9.6
4	5.9	6.7	6.6	7.6
Case III: $430K (new well- shorter lines)				
0	(185)	(244)	(211)	(280)
1	(13)	(161)	(129)	(211)
2	16.0	(73)	(43)	(139)
3	13.4	19.3	17.8	(69)
4	11.4	15.5	14.5	19.8
5	9.6	12.1	11.6	14.8

(x) means thousands of dollars lost (20 year life, present value) heating seasons. The primary monitoring data will be for the next heating and grain drying season. Figure 3 shows the project schedule for the bulk of the construction phase.

DIAMOND RING GEOTHERMAL PROJECT

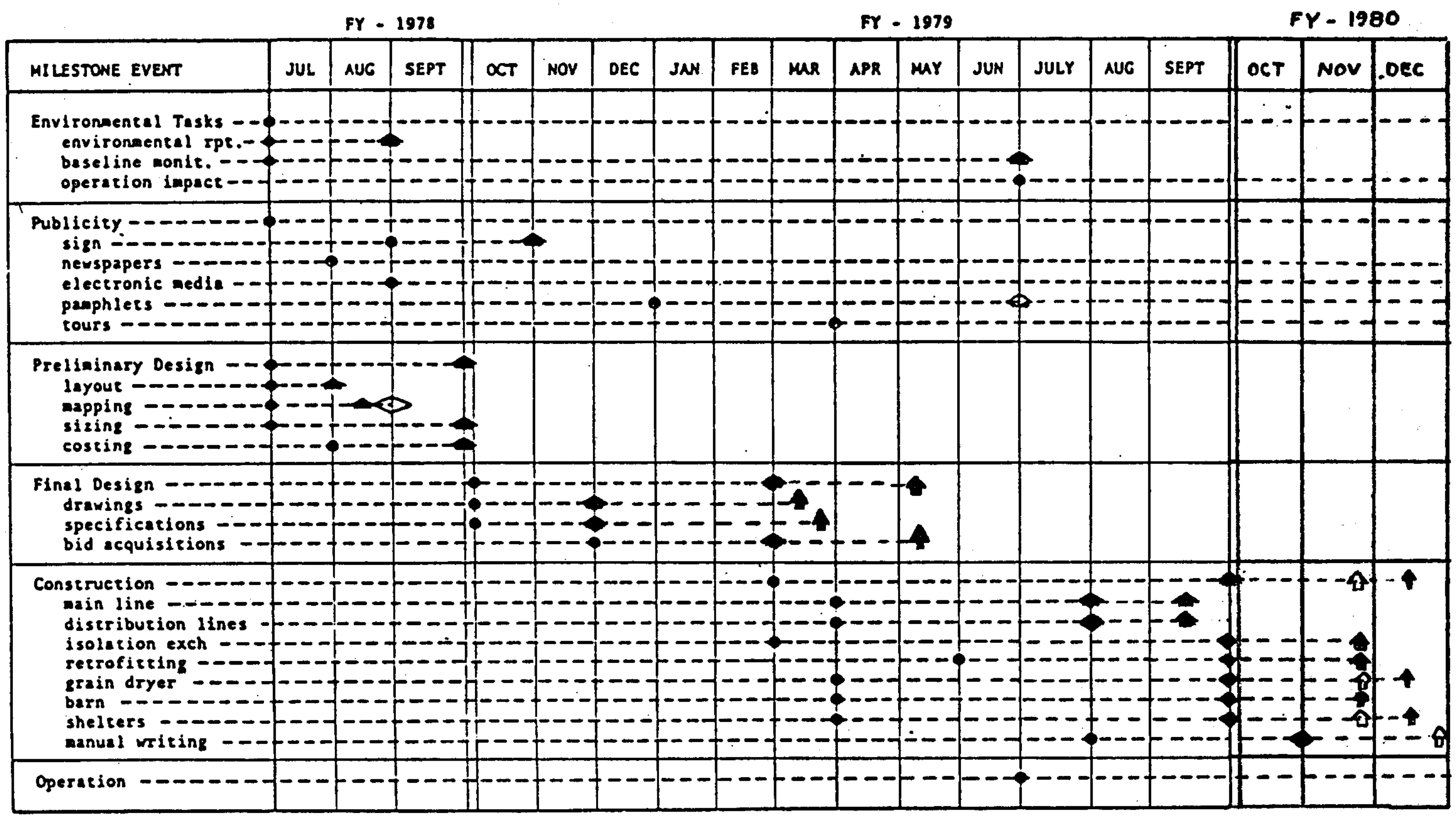


Figure 3.- Schedule

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR FOOD PROCESSING AT ORE-IDA FOODS, INC.

John C. Austin, P.E., Project Manager
CH2M HILL

I. PROJECT DESCRIPTION

INTRODUCTION

Approximately 115 food processors are located in the states of Idaho, Oregon, and Washington. Many of the processors have factories located along the Snake River Basin in Southern and Eastern Idaho. This region is believed to contain a major medium-temperature geothermal resource. For these processors located near geothermal resources, approximately 50 percent of the energy requirements could be provided by a geothermal water supply with temperatures of 300°F (150°C) or more.

With the escalating cost of fossil fuels, companies are faced with higher operating expenses and the possibility of restricted fuel supplies. Accordingly, interest has increased in alternate fuel sources such as byproduct and waste incineration, solar energy, and geothermal energy where available.

Extensive studies to utilize geothermal energy for one of these processors, Ore-Ida Foods, Inc. in Ontario, Oregon, have been completed. Several schemes were investigated to tap the earth's heat. The U.S. Department of Energy (DOE), in late 1977, announced a cost-sharing program in which companies, in partnership with the Federal government, would seek to develop and demonstrate the viability of geothermal energy. In these demonstration projects, a number of technical and institutional problems must be resolved, ranging from resource exploration to retrofit and operation of the plant on geothermal energy. The technology developed in these initial projects will be available to other industries and will serve to stimulate the development of geothermal energy at the commercial level.

The Ore-Ida facility is located on a 200-acre site near the northeast edge of the City of Ontario, Oregon (see Figure 1). The existing complex processes potatoes, corn, and onions into frozen food products which are shipped and marketed throughout the country. Process steam for peeling, blanching, frying, and cleanup is provided at 280 pounds per square inch gauge (psig) by natural gas-fired boilers with fuel-oil standby. This existing steam generation system will continue to supply high pressure steam to the fryers which have temperature requirements above the 300°F expected to be available from the geothermal resource.

It is planned that the geothermal resource be tapped by two production wells with a combined capacity of approximately 800 gallons per minute (gpm) and temperatures near 320°F.

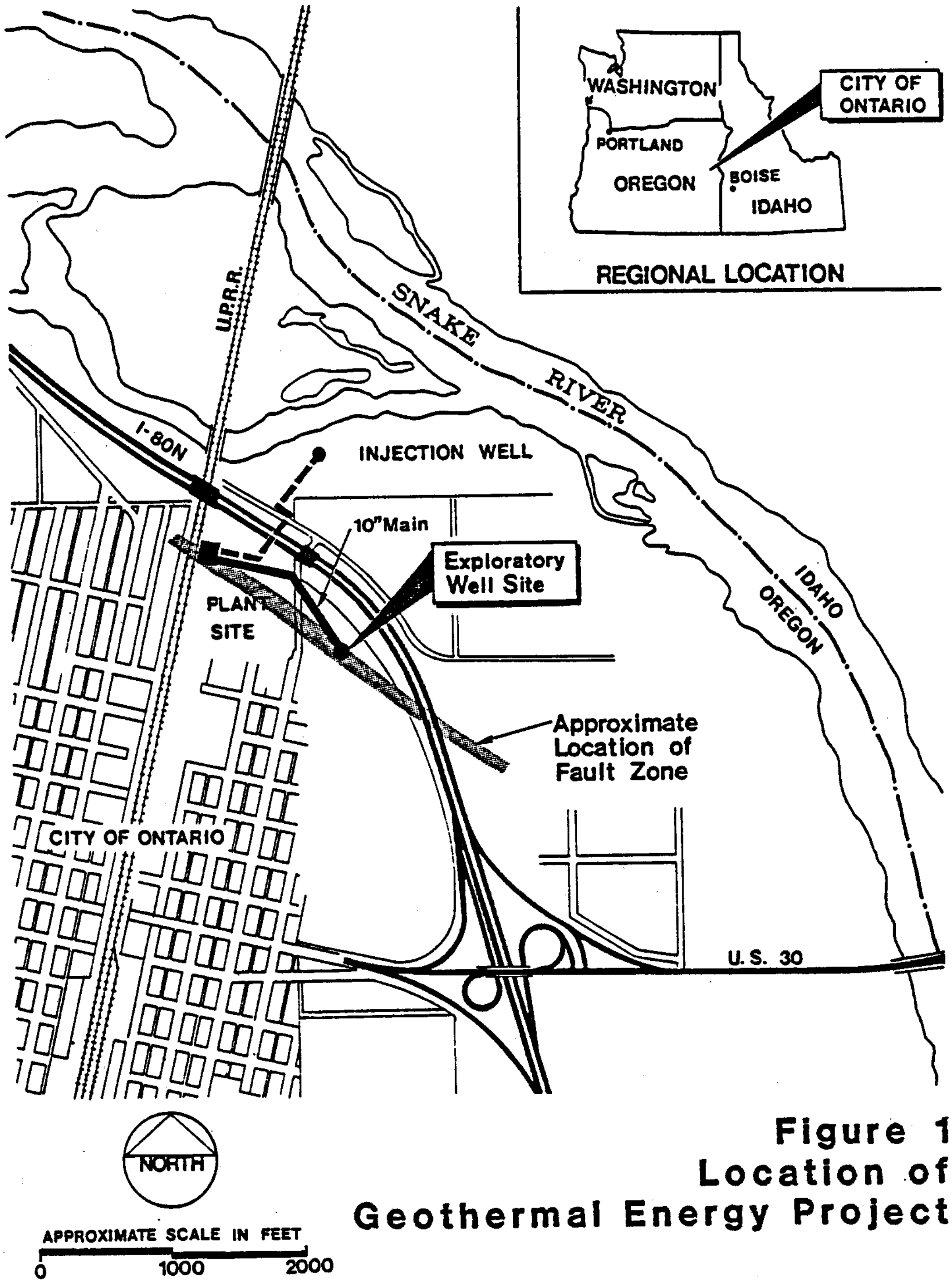


Figure 1
Location of Geothermal Energy Project

PROJECT DESIGN

The geothermal water will be transmitted from the production well field to the plant through a buried and insulated 10-inch (25.4 mm) steel transmission main. Under normal conditions, the pipeline is expected to operate at a pressure near 100 psig (689 kPa). The transmission main will terminate at a building housing the heat exchangers.

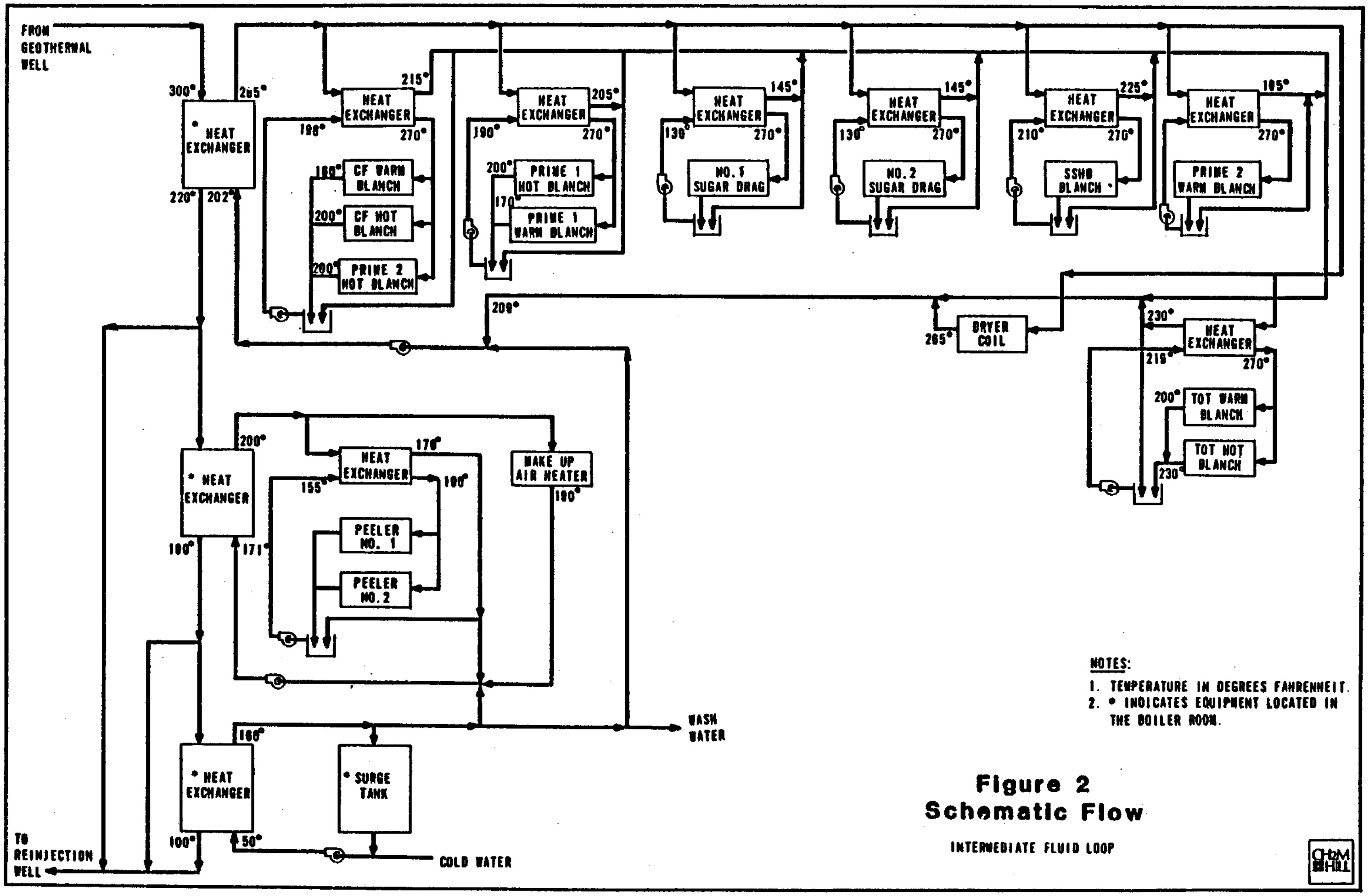
The geothermal well pumps will be 150 hp (112 kW) deep well turbines suitable for continuous operation within the well environment which may exceed 350°F (117°C) and is expected to be corrosive.

Plate heat exchangers will transfer the thermal energy from the geothermal water to the plant process water systems. This geothermal energy will supply the heat load requirements for several process operations which have temperature requirements below 300°F (150°C): hot and warm blanching, sugar drag, and drying of the food products. Generally in a geothermal system, operation and maintenance costs are not directly dependent on the amount of energy being extracted from the geothermal water. Therefore, due to the high capital costs, the user benefits by extracting as much thermal energy from the water as possible. This is usually accomplished by arranging heat loads in series. The geothermal water is distributed from processes which require the highest temperatures to those which use lower temperatures.

The conceptual design is based on the cascade principle - to extract as much of the energy from the 800 gpm (50 l/s) geothermal flow rate as possible. Figure 2 schematically represents the planned geothermal system. The hot and warm blanchers will drop the geothermal temperature from 300°F (150°C) to approximately 200°F (93°C). The sugar drags and peelers will further extract energy from the geothermal fluid to approximately 170°F (77°C). Space heating, domestic hot water, and process makeup water will subsequently lower the geothermal temperature to the 100°F (37°C) range. Fluctuations in the amount of energy required for these lower heat level cascade uses will cause the final geothermal fluid temperature to vary. The average reject temperature of the geothermal water will be approximately 130°F (54°C).

In the existing peelers and blanchers, live steam is injected directly into the process water as necessary to maintain the setpoint temperature of the process water. Heat for the sugar drags is provided by steam coils located in the sugar drag tanks. The present steam systems will be retained to provide a secondary source of heat in the event the geothermal system is down for maintenance.

A majority of the equipment will be operated continuously whenever the product line is in operation. Water and product flow rates vary, however, making the energy requirements for individual pieces of equipment fluctuate. The actual amount of energy required for each process will be controlled by pneumatic valves which will modulate to maintain a set process water temperature.



NOTES:

1. TEMPERATURE IN DEGREES FAHRENHEIT.
2. * INDICATES EQUIPMENT LOCATED IN THE BOILER ROOM.

Figure 2
Schematic Flow

INTERMEDIATE FLUID LOOP

The system will be fully instrumented with continuous pressure, temperature, and flow recorders to record accurately and calculate the actual amount of energy being derived from the geothermal source. The information thus obtained will be fed to a microprocessor which will calculate efficiencies, total energy usage, and energy costs.

Several secondary uses for the 130°F (54°C) geothermal water also are being considered. These include additional space heating in office buildings, maintaining temperatures in potato storage cellars, stabilizing wastewater temperatures for better treatment, and also, use in byproduct production. Potato storage requires maintaining the potato cellars at approximately 42°F (6°C) year around. The minimum heating required during the winter could be provided directly by geothermal water-to-air heat exchangers which would be located in the storage areas.

Additional uses of this low temperature geothermal water could include slab heating, greenhouse operations, and other suitable uses. When all of the useful energy has been extracted from the geothermal water, the spent fluid will be collected and transmitted by another steel transmission line to an injection well where it will be pumped back into the receiving aquifer.

Figure 3 represents the relative amount of energy supplied for simultaneous steady-state operation. The area indicated by each process is proportional to the amount of energy supplied.

The conceptual design indicates that approximately 50 percent of the present heat load can be provided by geothermal energy at 300°F (150°C) and below as illustrated. This represents approximately 89×10^6 Btu/h (26 MW).

GEOTHERMAL RESOURCE

The selection of a site for a geothermal test well program at Ontario, Oregon was based on a large body of regional and local geological and geophysical data from published and unpublished sources.

The Ontario, Oregon site is located in the center of the western Snake River Plain geomorphic province. This province is an arcuate structural and topographic depression which extends from about 25 miles (45 km) northwest of Ontario, eastward and northeastward across Southern Idaho, to the vicinity of Yellowstone Park, Wyoming. The western limb of the depression is referred to as the Snake River Basin. This basin is bounded on the north by the mountainous region of Central Idaho and on the south by the Owyhee uplift. At its northwest end, it is terminated against the Blue Mountains uplift of East-central Oregon.

The existence of geothermal potential in the Snake River Basin is suggested by the history of late Cenozoic volcanism and tectonic activity. This general evidence is supported by the occurrence of thermal waters in springs and shallow water wells around the basin margins. Further evidence occurs in the relatively high geothermal gradients encountered in some deep hydrocarbon exploratory test wells drilled in the basin.

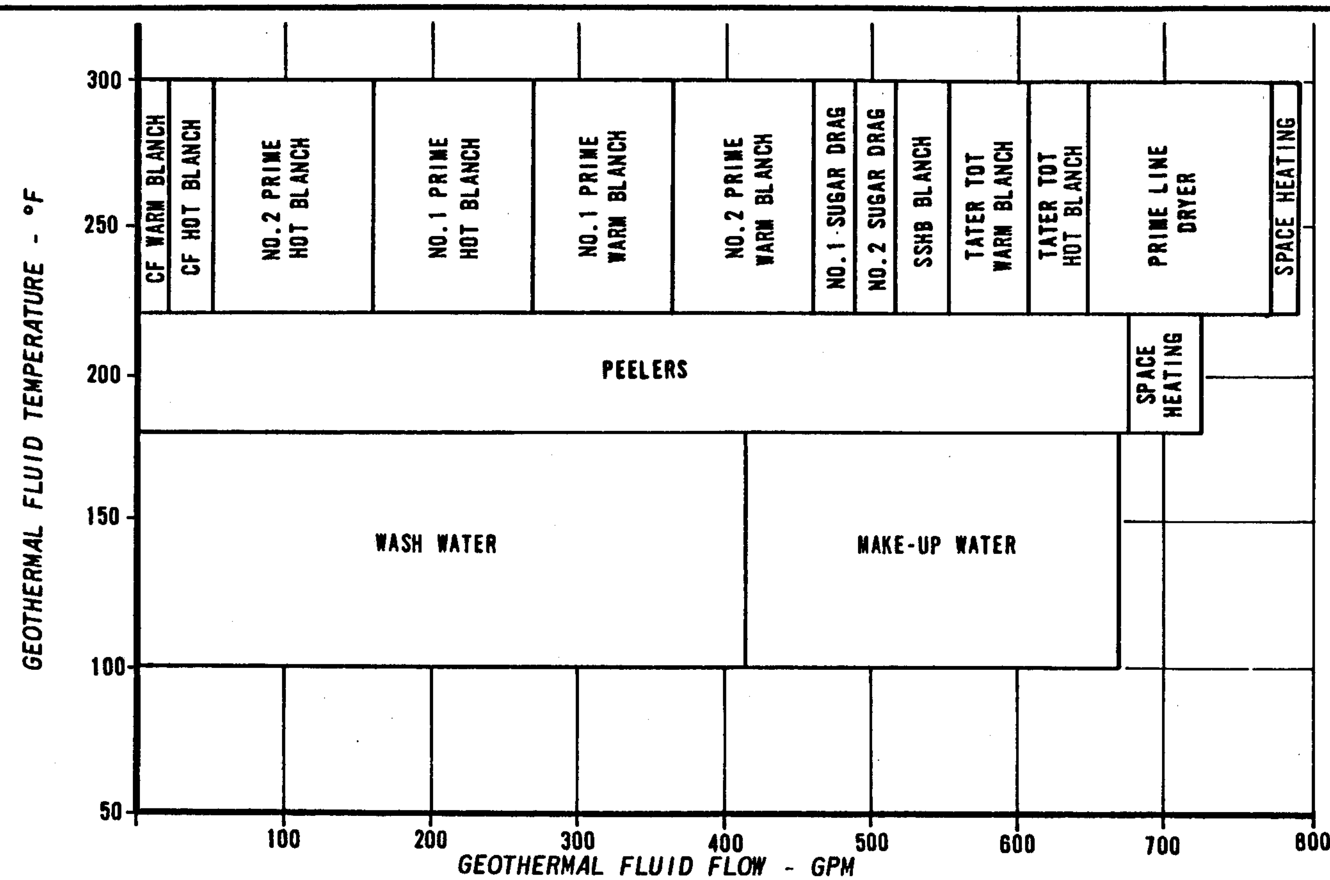


Figure 3
Energy Allocation
INTERMEDIATE FLUID LOOP

CH2M HILL

A limited amount of geothermal exploration has taken place in the basin, consisting of temperature-gradient hole drilling, geochemical studies of thermal waters, and local geological and geophysical work. Apart from small-scale local uses of thermal waters from hot springs and shallow wells, no significant geothermal production has yet been established.

Several factors must combine to provide a geothermal resource of significant value. These include the existence of elevated temperatures and porous rocks capable of producing a useful fluid volume. In addition, these conditions must occur at depths at which they can be exploited with economic advantage.

The surface in the vicinity of Ore-Ida is covered by varying amounts of alluvium overlying poorly-lithified sediments of the Upper Idaho Group. Exposures of bed-rock are too poor to permit field mapping of any structures that might be present. Interpretations of aerial photographs to define geomorphic lineaments of possible structural origin are not known to have been made in this area. On the basis of regional gravity data, the site is located on the west flank of the north-trending gravity high and at least 5 miles north of the major northwest-trending anomaly. Although the structural significance of these features is uncertain, it is probable that the site is in a relatively structurally low part of the basin, although not in one of the deep closed lows appearing on the gravity maps.

All of the detailed structural data related to the site were derived from six reflection seismograph lines surveyed for this project. The quality of the seismic data vary from excellent to poor. Seven possible faults were detected.

The well sites were selected based upon information obtained from a seismic survey that indicates there is a potential structural fault zone running northwesterly through the plant site. It is expected that the fault zone would be more permeable and produce more water than a location not associated with a fault.

Based on the available geologic data, two production wells are planned. The production wells should have a combined capacity in excess of 800 gpm (50 l/s) and temperatures near 320°F (160°C).

PROJECT ECONOMICS

The cost of the geothermal demonstration project is currently estimated at nearly $6 million. Of the total project cost, Ore-Ida Foods is scheduled to finance more than 50 percent. The remainder of the project will be funded by the government with a major portion of the Federal funds being spent during the resource assessment and well drilling operations. These phases represent the most significant risk in developing a viable resource; a risk which would have prohibited total project financing by the food processor. Federal assistance has bridged the economically restrictive first phase. If the resource is proven, the processor will finance a majority of the construction and retrofit phases of the project.

Based upon the initial estimates and projections of fossil fuel costs, a return on total project investment is anticipated at approximately 18 percent. As fossil fuel costs continue to increase, the economics of the geothermal system will improve concurrently. The system is expected to successfully demonstrate geothermal energy's role in supplying an alternative to fossil fuels for low-grade energy needs.

II. PROJECT STATUS

The technical scope of the Ore-Ida project has varied little from the conceptual design first presented to DOE in November of 1977. Plant retrofit plans and replaced heating loads are essentially unchanged. No major changes are anticipated from these early conceptual plans. Presently the preliminary design is complete. This preliminary design establishes the parameters for pipeline sizes, location of wells, major equipment sizing and layout, and possible cascade or secondary uses of the geothermal fluid. The major recent project activity, aside from the preliminary design, has been the drilling and completion of Ore-Ida No. 1 well.

The Ore-Ida Foods No. 1 well is located in the northeast quarter of Section 3, T. 18 S., R. 47 E., in the town of Ontario, Malheur County, Oregon. The drilling contractor was Montgomery Drilling Company, Bakersfield, California, using a National 55 rig.

The well was spudded in at 9:00 a.m. August 18, 1979. A 17-1/2-inch hole was drilled to 925 feet, where 13-3/8-inch casing was set on August 22.

After installing the blow-out preventers, drilling resumed in a 12-1/4-inch hole from 925 to 7,154 feet, where geophysical logs and temperature surveys were run on September 18 to 20. Drilling continued to 7,958 feet, where a second set of geophysical and temperature logs were run on October 1 and 2. The mud was gradually changed from about 67 pounds per cubic foot (pcf) at 925 feet, to 82 pcf at 7,152 feet. This change was made to control sloughing and to keep the hole clean. Drilling continued to a depth of 8,188 feet. Core number 1 was cut from 8,188 to 8,216 feet. Twenty-six feet of core were recovered. Then 9-5/8-inch casing was run to 8,183 feet. Below 8,183 feet, an 8-1/2-inch hole was drilled to a total depth of 10,054 feet, reached on November 8. The drilling fluid was changed to water from 8,183 to 8,400 feet. Drilling in this interval was characterized by excessive sloughing and fill on bottom culminating in a stuck drill pipe. The mud weight was built back to 83 pcf and the bad drilling conditions were corrected. On reaching the total depth, geophysical and temperature logs were run from November 8 to 10, and a 7-inch slotted liner was suspended from 8,142 to 10,038 feet on November 13. The slots extended from 8,187 to 10,036 feet, are 125 mesh, in 8 rows, 2 inches long, with 6-inch centers. The testing operations were conducted from November 16 to 18 and from November 24 through 27.

The Ore-Ida Foods No. 1 well was drilled in order to develop a flow of 800 gpm of water at about 320°F. The actual conditions found are summarized as follows.

Equilibrium temperatures of 300° F occurred at a depth of about 7,000 in the Ore-Ida well. The gradient continued to increase at an average rate for the remainder of the hole to a total depth of 10,054 feet. The equilibrium temperature at total depth is estimated to be near 400° F. It appears that the project temperature requirements can be met at economically attractive depths in the Ontario area, if an adequate fluid flow could be obtained.

The rocks most likely to contain reservoir potential within the depth interval of favorable temperature are basalt flows. Basalt units are interspersed through the Ore-Ida well section from a depth of 4,570 feet to 8,135 feet, and an aggregate of 1,425 feet of flows occurs in the 1,919 foot section below a depth of 8,135 feet. However, the depth to the top of this predominantly basalt section is approximately 2,000 feet deeper at the well site than had been inferred from reflection seismograph data. Although a thick section of basalt has been penetrated, no important zones of high porosity and permeability were encountered. Large basalt intervals have been included in formation tests but there is no evidence that diffuse fractures are capable of producing an aggregate fluid volume approaching a useful level.

PROJECT SCHEDULE

As discussed in the previous section, the drilling of Ore-Ida No. 1 well has not resulted in development of a geothermal resource at Ontario. Significant slippage has occurred in the project schedule due to the extended drilling operation and test procedures. Currently, the well capability is being evaluated and other project alternatives which can be pursued are being reviewed in an effort to reach the program goal of 50 percent plant retrofit to geothermal energy. Several major project decisions are expected to be made in the next 3 months. These decisions, based upon project economics and the potential for an exploitable resource, will necessitate major adjustments to the program schedule.

PROJECT COST

Currently, total project expenditures are at $2 million, including Ore-Ida's cost share items. An area of significant under-budgeting occurred with the well drilling operation. Approximately $1 million was budgeted for the drilling operation, based upon an original target depth of 7,000 feet. Costs for drilling the 10,000-foot plus deep hole have exceeded the original estimates.

The anticipated cost changes for future project activities is dependent on future project plans. Until such time as those plans become formalized, firm project cost changes cannot be predicted.

III. FUTURE PROJECT ACTIVITY

Several alternative methods are being considered to provide the necessary geothermal flow rates to the Ore-Ida facility. These include: 1) stimulation techniques on the existing Ore-Ida No. 1 well to improve the flow rate; 2) drilling a second geothermal well in a better-defined fault zone some 1-1/2 miles from the plant; and

3) transporting geothermal fluids from a well field site remote from the plant site. Pipelines in this third alternative may range in lengths between 5 miles and 20 miles. The risk associated with each of these alternatives is presently being reviewed. This review will include economic and technical feasibility, institution, and environmental concerns for the project.

ACKNOWLEDGEMENTS

The author is indebted to Dr. Murray Gardner of GeothermEx Inc. who prepared the geologic interpretations of the region and provided the drilling log status.

This work has been supported by the U.S. Department of Energy.

MADISON COUNTY GEOTHERMAL PROJECT

REXBURG, IDAHO

PROGRAM MANAGER: DR. J. KENT MARLOR, CHM.,
MADISON COUNTY ENERGY COMMISSION

ENGINEERS: ENERGY SERVICES, INC., IDAHO FALLS, ID

AUTHORS: JAY F. KUNZE AND ROGER C. STOKER

BACKGROUND

The Madison County Geothermal Project is a combined industrial process and space heating application located in and around the City of Rexburg, Idaho, on the eastern margin of the Snake River Plain. The project resource area is defined by a nominal 3½-mile radius circle centered on Rexburg. (Figures 1 and 2). Resources beyond this distance generally become uneconomical to transport to the city for space heating use.

The project will supply industrial food processing energy for a large potato granule plant operated by the Rogers Potato Division of AMPCO Foods, Inc., as well as some space heating requirements for the City of Rexburg.

Rexburg has a population of 10,773 plus an additional 6,000 students that attend Ricks College. Rogers Potato Division operates the potato granule processing plant just at the north edge of Rexburg, processing 250,000,000 pounds of potatoes annually. Rexburg has a yearly heating demand of approximately 8,500°F days.

1. Project Description

Resource

The resource is the warm water that is known to exist all along the boundary of the Snake River Plain. Minimum temperatures of 120°F are being sought. Two intermediate depth slim geological test holes were drilled in the fall of 1979, and from these a site for a deep drilling exploration well has been selected. This site is at the southern edge of the city of Rexburg, within half a mile of Ricks College and one mile from the heart of downtown Rexburg.

The slim geological test hole data indicates that minimum gradients of 3°F/100 feet can be expected below the main near surface aquifer. Hence, temperatures of 130°F are anticipated at depths of 3,000 feet, and 190°F at 5,000 feet. The target drilling depth for the deep exploratory hole is 5,000 feet. The drilling specifications, and the bid package which has been issued, call for drilling to begin before June 1, 1980. The well design is shown in Figure 2.

Design

The minimum expectation is 120°F water, useable for space heating. Since pipeline transport distances will be very short, because of the location of the well so near to the downtown area, both pipeline design and economics should present few problems. Temperatures of 200°F are desired for use in the potato processing plant.

System Economics

Rexburg is a particularly attractive location for a demonstration space process heating project, because of the very high conventional fuel costs in the area. Natural gas is available for home heating, but the cost is \$5.30/ million Btu. Many homes have electric heat, installed when such heat was being promoted as cheap and clean (as late as 1973). Current winter-time electric rates are nominally 4.1 cent/KWh, or \$12.00/million Btu. The climate is generally too cold to make air-to-air heat pumps very attractive, since these only have a seasonal average C.O.P. of approximately 1.55. Thus geothermal energy has very favorable competitive economics in the town of Rexburg. The project is being lead by the Madison County Energy Commission, a public agency reporting to the County Commissioners. It thus cannot take advantage of the various tax-incentives to promote the development of geothermal energy. However, if the initial well finds water approaching 200°F, it is expected that the American Potato Company will proceed with the drilling of a well to serve its facility at the north edge of Rexburg. Similar 200°F temperatures must be found before Ricks College could justify the conversion of its present coal-fired steam heating system to geothermal energy.

Potential energy-displacements from the present consumption of fossil fuels or electricity for space heating are as follows:

Downtown businesses, schools, etc.	1.6×10^{11} Btu/year
Homes within the citylimits	3.0
American Potato Co. Plant Process	1.8*
Ricks College Campus	1.3

* This represents only 40% of the total process heat used at the American Potato Co., Rogers Food Division Plant. A minimum temperature of 220°F is needed to displace this amount of presently used fossil fuel (oil and gas). If the wellhead temperature is 300°F, approximately 90% of the present usage could be displaced.

Total potential displacment of fossil fuels by geothermal energy represents $3.5 million per year at present fuel costs. The total project costs are projected as $3.7 million. Madison County, the developing agency, could nominally charge about half of the current fossil fuel costs for its service of supplying geothermal energy. Thus the apparent payback period is 2 years. However, it will take a number of years to acheive the conversion of the many homes and other small buildings to geothermal energy, once the main pipelines are laid.

II. STATUS

The scope of the project, as originally proposed, recommended, that the deep probing for a very hot resource useable for potato processing be undertaken before drilling the many wells that will be needed for the space heating needs of the entire city of Rexburg. However, the changing economic conditions have led to the American Potato Co. revising its priorities, and deciding not to participate in the project until the Madison County Energy Commission proceded with its program and confirmed that adequate temperatures were available.

Because the area was not geological explored to the extent deemed necessary for siting the deep well, preliminary geological test holes were drilled this last fall to better understand the nature of the geological structure in the bench area near Rexburg and the boundary of the Snake River Plain. About 10% of the drilling budget had to be extracted for the drilling of these test wells. This drilling also delayed the drilling of the first deep well by about 6 months.

III. LESSONS LEARNED

The present tax incentives and tax benefits to promote the development of geothermal energy proved to be less than adequate in the case of this project. A company that is not unusually profitable will probably not risk the development of geothermal energy, particularly in times of economic contraction. Fortunately, this project is a partnership of a private company and a public agency, and the partnership arrangement has enabled the project to proceed nearly on schedule.

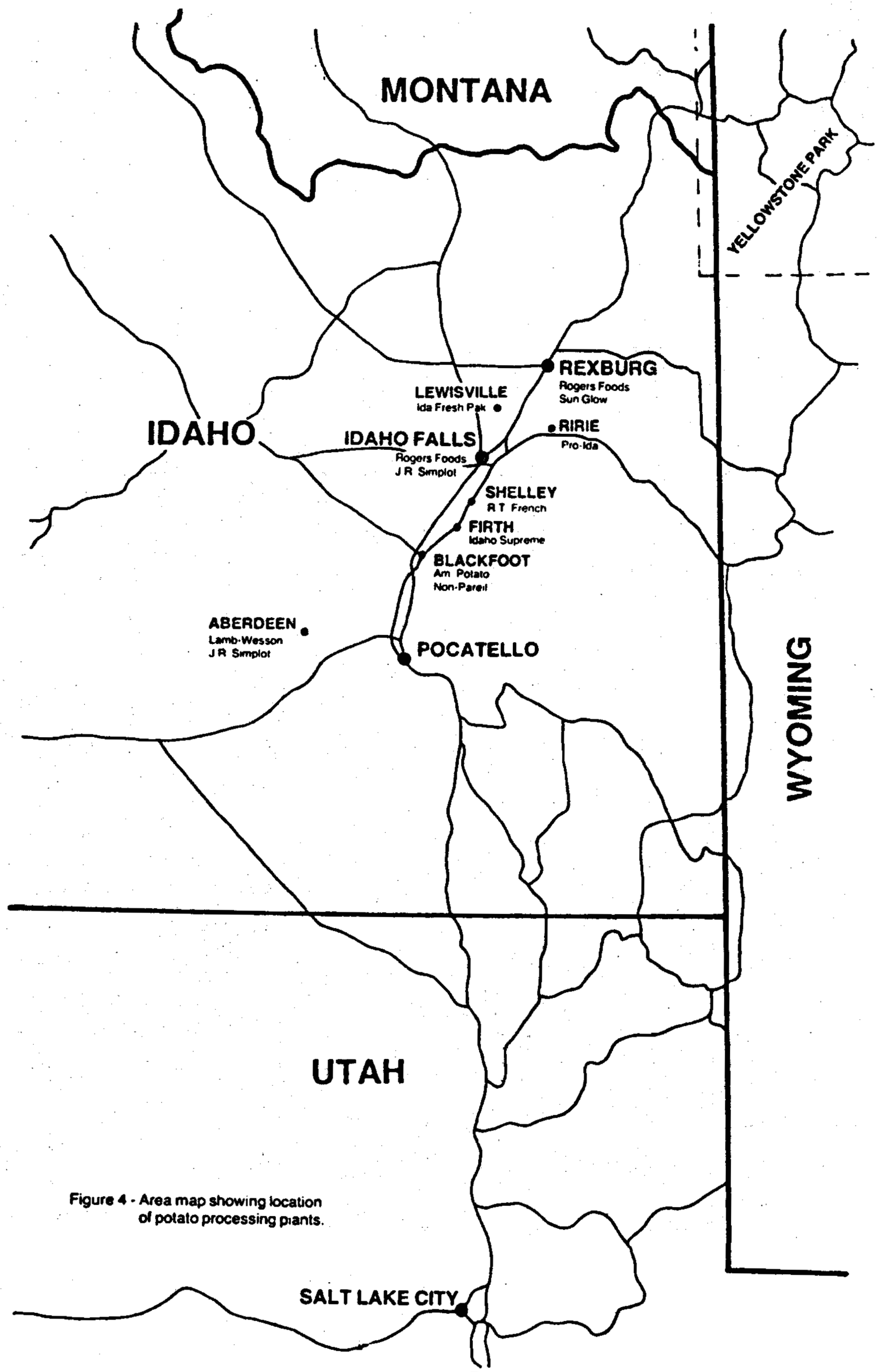
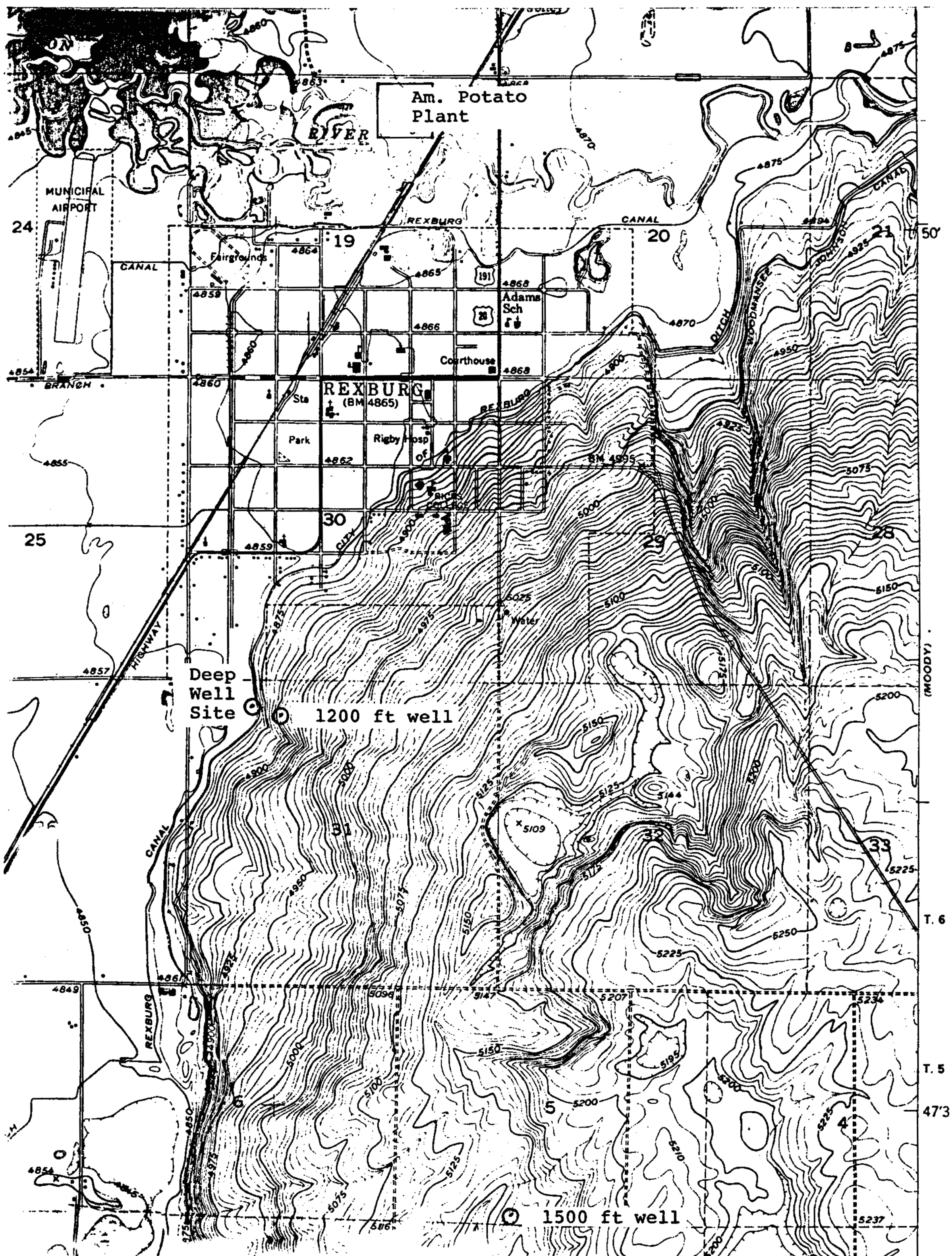


Figure 4 - Area map showing location of potato processing plants.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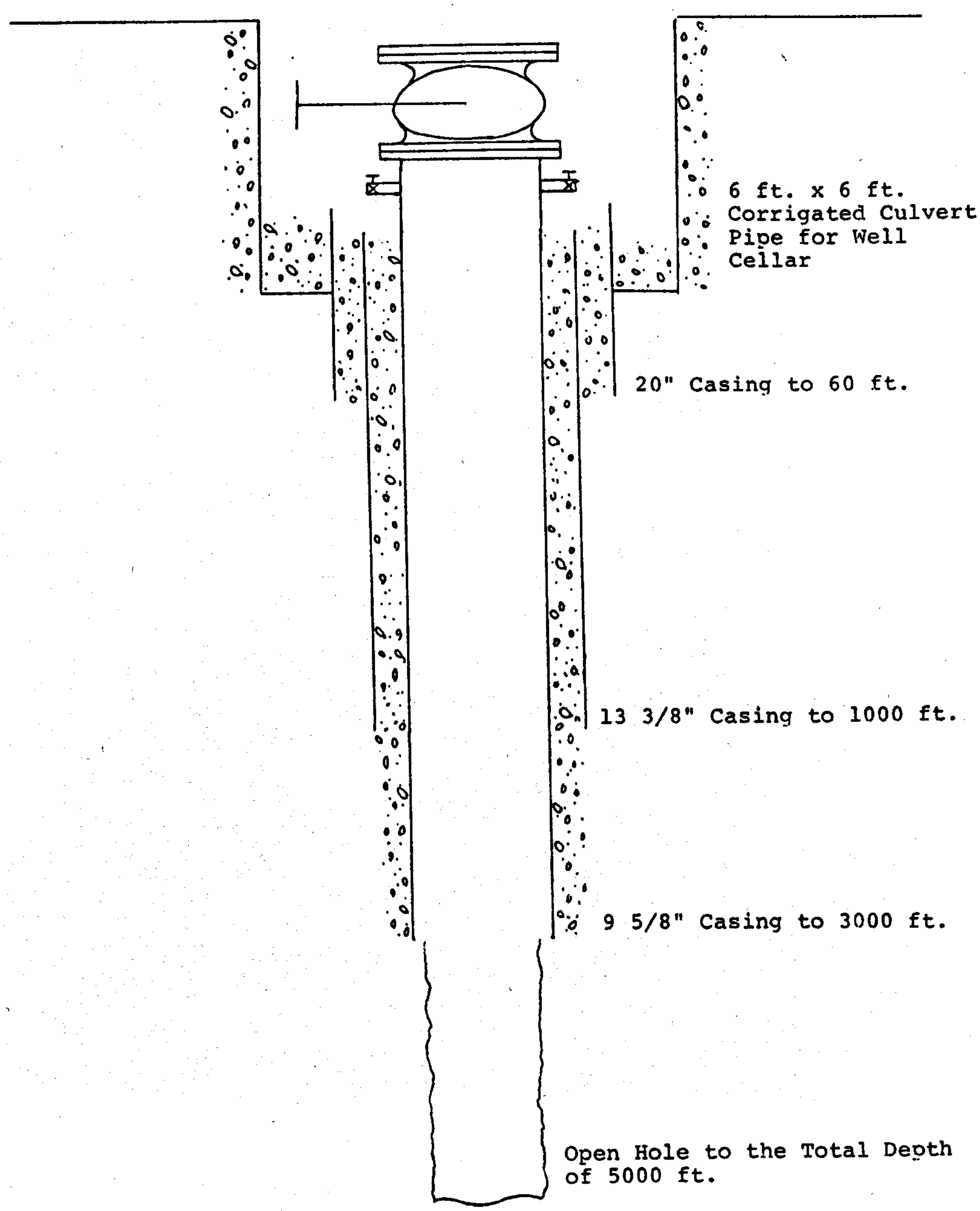
MADISON COUNTY WELL PROFILE



GEOTHERMAL ENERGY FOR SUGAR BEET PROCESSING

JAY J. SEIDMAN E. LEE LEVENTHAL, P.E.

ABSTRACT

The commercial exploitation of geothermal energy is being implemented at a sugar beet processing plant in Brawley, Calif. under the auspices of the Department of Energy. This program capitalizes on the geothermal energy potentially available from a company-owned resource and applies the energy directly to the processing of sugar beets in their facility. At its completion, the program will provide energy to replace over 225,000 barrels of fuel oil per year (more than two-thirds of the current plant consumption) by a technically straightforward, economically sound and environmentally acceptable geothermal application. This paper describes the geothermal resource, the technique for transporting the geothermal energy to the beet processing facility and discusses the various tradeoffs and configurations within the facility that interface and use the geothermal energy.

INTRODUCTION

Under the sponsorship of the Department of Energy, a system is being developed for supplying geothermal energy to the processing of sugar beets. The objectives of this Geothermal Sugar project are to satisfy DOE's goal of near-term commercialization of direct utilization of hydrothermal resources by the private sector of the United States' economy. The specific objectives of this project are to:

- Demonstrate the technical, economic and environmental attributes of geothermal energy in replacing fossil fuels for commercial applications of industrial process heat;

- Demonstrate that geothermal systems can provide reliable, cost effective operation for critical functions, operated continuously for periods of several months;

- Determine the economic, conservation and environmental attributes of geothermal systems for various process heat applications based on where the heat is either used completely by one portion of the system or alternatively used sequentially by different components with different applications (cascaded);

- Identify a specific set of commercial users and show how their processes can be integrated into the Holly Sugar Brawley complex to the economic advantage of all and with significant savings in conventional energy;

- Disseminate data which demonstrate that geothermal systems are practical and profitable in this area and in other known geothermal resource areas (KGRA's);

- Promote public and industrial awareness of the beneficial attributes of geothermal systems.

Jay J. Seidman, Program Manager, Energy Systems Management Division, TRW Systems and Energy.
E. Lee Leventhal, Project Manager, Energy Systems Management Division, TRW Systems and Energy.

Prior to the initiation of this project, TRW and Holly (1) performed a study which concluded that the present state of technology provides economic benefits from using geothermal heat for sugar beet processing and for crop drying. A conceptual design was developed as part of this study which included the use of known geothermal reservoirs in the area of the Holly Sugar plant to furnish thermal energy in a proposed retrofit of an energy intensive sugar beet processing system. The system was based on 350°F (177°C) brine which could be used at various process steps, including process makeup steam, beet pulp drying and refrigeration systems. Potential post-campaign (periods when sugar beets are not being processed) uses are alfalfa drying, greenhouse operation and power generation. Campaign periods last from the beginning of April to mid-August and well drilling and component installation are correlated to the sugar beet campaign. The program is divided into three phases: Phase I is System Design and Analysis, Phase II installs and evaluates a pilot system and Phase III installs and operates a total system.

The Holly facility in Brawley is located near the Brawley KGRA (8 miles away) and close to a recently successful exploratory geothermal well (1 mile away). Geological and geophysical analysis indicate this is a prime area for the possible existence of a geothermal reservoir. The ready availability of geothermal energy so close to the existing facility results in a minimum of adaptation and construction to the Holly facility. Modification of the facility for the use of geothermal energy is shown in Fig. 1 and further defined in the retrofit plot plan of Fig. 2. The location of the geothermal well, on Holly property, is shown in Fig. 3.

EXISTING FACTORY

Extraction of sugar from beets and the dehydration of beet pulp is a very energy intensive process. Approximately 60% of the cost of pulp processing is attributable to fuel costs. The sugar refining process may be conveniently separated into the following stages (Fig. 4):

- Diffusion Stage (A). Sugar beet roots are thoroughly washed in preparation of slicing and transported by flume from the receiving yard to the slicers. The beets are sliced into thin strips called cossettes. The slicers require live steam at 150 psig (1033.5 kPag), minimum for blade cleaning. The cossettes are then immersed in hot water, leaching out the sugar by diffusion. The temperature is raised for better extraction, using vapors formed in the second evaporator effect.

- Juice Purification Stage (B). The raw diffusion juice is screened to remove any small particles of cossettes and then heated to 175-185°F (80-85°C), using vapors formed in the third evaporator effect described below. The heated raw juice is then purified by a process called carbonation in which lime and carbon dioxide gas are added to precipitate the impurities in the juice. Filtration and settling remove the solid particles and eliminate impurities. The purified liquid is called thin juice and contains 10-15% sugar solids.

- Evaporation Stage (C). The thin juice is preheated using first and second vapors and exhaust steam and sent to the evaporators. The thin juice is concentrated by evaporation in multiple-effect evaporators, with five individual bodies or effects. The evaporators are arranged in a forward feed arrangement, with steam used for the first effect drawn from turbine exhausts but, for each succeeding effect, the steam used is that formed in the preceding effect by evaporation of water from the juice. This system is economical since it allows ~~multiple~~ use of the same heat energy and results in decreasing temperatures and pressures as the juice proceeds through the effects. The thick juice outflow is concentrated by evaporation to a dissolved sugar solid content of 50-65%.

- Crystallization Stage (D). Further filtering ensures that all solid particles are eliminated. The sugar is then crystallized by pan boiling in vacuum pans. Low temperature pan boiling heat is provided by second vapors to avoid caramelization. The resulting mixture of sugar crystals and liquid from the pans is known as fillmass. The fillmass is spun and washed in high-speed centrifuges to separate the sugar crystals from the liquid. The wet, white sugar crystals are then sent to the dryer or granulator and from there to the cooler. The granulated sugar is then screened and either sacked immediately or stored in bulk bins to await further packaging or bulk delivery.

- Dried-Pulp Manufacturing Stage (E). Wet pulp from the diffuser is pressed in pulp presses to reduce the moisture content from 95% to 80%. The pressed pulp is then mixed with molasses, from the centrifuge, and dried to a moisture content of about 10% by hot air in a pulp dryer. A conventional pulp dryer is direct-fired with an induced-draft, parallel-flow, rotating drum. The drum, approx. 12 ft (3.66 m) in diameter and 60 ft (18.3 m) long, contains baffles which drop the pulp through the hot flue gases as the drum rotates. The pulp is moved through the drum by the flow of combustion gases as the drum rotates. The drums are normally oil-fired with products of combustion mixed with air to obtain a nominal entering temperature of 1200°F (650°C) to prevent losses from pulp combustion. The drum discharges through a draft to a cyclone separator to recover small particles from the flue gases existing at 230 and 280°F (110 and 138°C).

Beet pulp drying offers the greatest opportunity for fossil fuel savings from geothermal application since it represents approx. 44% of the total Brawley factory fuel demand.

The beet sugar refining process requires relatively large quantities of low-pressure process steam and electromechanical energy. Holly generates its own electric power with a noncondensing steam turbine generator, which exhausts steam at the pressure required for process heat. Steam is also used to power other large horsepower loads with mechanically-driven noncondensing steam turbines.

The boiler steam pressure is based on exhaust steam pressure required by the evaporator first effect and the amount of power to be generated by the turbine prime movers. The boiler steam pressure selected allows generation of the required power with approx. 65% of process steam required by the factory. The remaining 35% is made up by throttling live steam into the effluent stream.

Oil and gas are used as boiler fuels. Sugar factories in California have interruptible gas supplies and must use oil for either primary or standby fuel.

The nominal boiler and exhaust steam balances for the 1976 sugar campaign indicate the throttled steam makeup is approx. 35% of the total process steam demand. This throttled steam makeup can be provided completely by geothermal energy without upsetting the balanced fixed turbine exhaust system.

Sugar campaigns at the Brawley factory last approx. 4-1/2 months with the factory operating 24 hr. a day, 7 days a week. Geothermal energy application to this process appears to be economically attractive even for this short season. Alfalfa or citrus pulp drying in the off-season could further enhance its economic attractiveness.

SYSTEM DESCRIPTION

Different system configurations have been studied and analyzed to determine the most cost and energy effective boiler/dryer/well combination. The geothermal fluid is used to generate the makeup process steam and to provide heated air for beet pulp drying. A typical configuration for the sugar processing, using geothermally derived energy, is shown in Fig. 5. The actual configuration selected will be dependent on the temperature and flow realized from the test well during the Phase II portion of the program. If the temperature and other characteristics of the brine are in the optimum range (≃450°F, <10,000 ppm dissolved solids, >1000 gpm/well), then the other boilers in Fig. 5 may also be replaced.

The selected application areas and geothermal fluid requirements are:

1. If the brine temperature is about 350°F (177°C) –
   - about 77,000 lb/h (9.7 kg/s) at 267°F (130°C) steam for Cooper evaporators, thin juice boiler and thin juice heater;
   - 2.75 million lb/h (346.5 kg/s) heated air for pulp drying.
2. If the resource is at a higher temperature, it will be possible to provide steam for:
   - the Swenson evaporators and smaller pieces of equipment requiring a total of 142,000 lb/h (17.9 kg/s) steam at 293°F (145°C);

- The beet slicers requiring 11,500 lb/h (1.45 kg/s) steam at 366°F (186°C).

In addition to these process heat requirements, the sugar factory utilizes about 4000 kW of electric power and 970 kW mechanical power presently supplied by gas/oil fired boilers.

GEOTHERMAL ENERGY EXTRACTION SYSTEM

The planned Brawley factory retrofit will use the geothermal fluids pumped from production wells, each producing at the nominal rate of 1000 gpm (63 ℓ/s). Heat will be extracted from the fluids for heat exchangers and the cooler fluid will be injected back into the reservoir through injection wells. Injecting the spent fluid back into the reservoir is becoming standard practice in the geothermal industry since spent fluid disposal by this method is environmentally sound and reservoir pressure is maintained to increase reservoir longevity and prevent subsidence.

Present plans also call for directionally drilling the production and injection wells from a single drilling island to the proper bottom-hole location (Fig. 3). An 80-acre production bottom-hole spacing is planned together with a five-spot production/injection well pattern. This spacing will be better defined after the reservoir has been tested using the initial wells.

Present plans call for wells of not more than 8000 ft (2450 m) total vertical depth with a total deviation from the vertical of less than 45 deg. The first wells drilled in Phase II will be to 8000 ft (2450 m) stepped out from the McCulloch Mercer 1-28 well. Subsequent wells may be reduced to 6000 ft (1830 m) based on tests and the history at Heber and East Mesa.

Expected geothermal fluid characteristics are as follows:

• Temperature	350°F (± 25°F) (180°C ± 15°C)
• Total dissolved solids	30,000-50,000 ppm
• Production rate	1000 gpm/well (63 ℓ/s) (± 10%)
• Injection rate	1350 gpm/well (82 ℓ/s) (± 10%)

STEAM GENERATION SYSTEM

In the retrofit (Phase III) portion of the program, the steam generation system will include geothermal boilers manifolded such that individual boilers can be removed from service for cleaning or maintenance without affecting the operation of the remaining boilers. The boiler will produce a total of 77,300 lb/h (10 kg/s) of 267°F (130°C), 25 psig (170 kPag) (saturated) makeup steam in the shell using 3800 gpm (243 ℓ/s) of geothermal fluid flowing through the tubes.

The planned steam generator configuration is a commercially available tube and shell heat exchanger with 2000 ft^2 (185 m^2) of heating surface. The tubes will be 1-in. O.D. mild carbon steel with operating tube velocities of 5-7 ft/sec (1.5-2.1 m/s), based on test findings of the San Diego Gas and Electric Co. at Heber with geothermal temperatures and salinities similar to those expected for the wells. Boilers are expected to operate in excess of 30 days between cleaning. Expected downtimes of 15-30 min. for cleaning will be verified during pilot plant operation. The pilot system will include one boiler and one pulp dryer similar to one of the systems shown in Fig. 4 or 5. The steam from this boiler will be dedicated to the thin juicer heater during Phase II pilot plant operations and will be manifolded into the total system during Phase III.

PULP DRYING SYSTEM

The Brawley factory beet pulp nominal drying requirements when processing 600 tons of beets per day (5.5 tonnes/day) are as follows:

		Wet Pulp		Dry Pulp
Solids	19%	25,650 lb/h (3.24 kg/s)	91.5%	25,650 lb/h (3.24 kg/s)
Water	81%	109,350 lb/h (13.81 kg/s)	8.5%	2,380 lb/h (0.30 kg/s)
Total	100%	135,000 lb/h (17.05 kg/s)	100 %	28,030 lb/h (3.54 kg/s)

Several pulp dryer types were investigated during the conceptual design study, including rotary water tube, rotary steam tube, rotary air and conveyor belt. It was determined that either a three-pass drum rotary air dryer or a 2-stage conveyor belt dryer would accomplish the required long, low temperature dwell time. The commercially available rotary air dryer is approx. 12 ft (3.66 m) in diameter by 42 ft (12.8 m) long and is the largest practical size for transportation to the site. The conveyor belt dryer is 14 ft (4.25 m) wide and 171 ft (50 m) long and would be transported in sections. The conceptual design, as corroborated by Heil and other dryer manufacturers, indicates that the low air temperature (275-300°F) (135-150°C) dryer is much less effective than a high temperature dryer. Specifically, for the same volumetric flow of the drying stream, the rate of flow of pulp may have to be reduced by a factor of five to six, and the required residence or dwell time of the pulp in the dryer increased by a factor of four to five.

We shall install only one pulp dryer in the pilot subsystem because of anticipated optimizing test manipulation of multiple variables during pilot plant operation. This one pulp dryer will also be monitored for particulate emissions after operating conditions have been optimized, and the results will be used in designing proper gas scrubbers for the dryers, if required.

GEOTHERMAL FLUID HANDLING SYSTEM

Geothermal supply and return pipelines between the wellheads and the factory will be installed during Phase II. The geothermal fluid piping system will be closed from the downhole production horizon to the downhole injection horizon, with system pressure maintained above saturation to prevent flashing within the system.

PILOT PLANT SUBSYSTEM

A pilot segment of the proposed retrofit, including one production well, one injection well, one boiler, one dryer and associated piping, will be installed and operated during Phase II (1980). The pilot plant will be operated to verify equipment performance and to evaluate and establish design and operating requirements of wells, boilers and dryers to optimize fossil fuel displacement and effectiveness. Test plans will include experiments to determine base performance characteristics under varying conditions.

CHARACTERISTICS OF THE ENERGY DEMAND AND THE REQUIRED GEOTHERMAL RESOURCE

Typical Brawley factory sugar campaign energy demands and geothermal application potentials are indicated in Table 1.

LIFE CYCLE COST AND SAVINGS

The proposed geothermal retrofit of the Holly factory is expected to cost about 12 million dollars in direct capital and will save about 225,000 barrels (35.8×10^6 ℓ) of fuel oil in each sugar campaign. The before-tax rate of return on the investment (undiscounted) would be about 25% at a delivered price of \$12/bbl (\$0.075/ℓ) for the oil that is saved, and 27.5% at \$14/bbl (\$0.09/ℓ). This return will come from seasonal sugar operations alone, which use the wells and dryers for less than half of each year. During the rest of the year, the wells and dryers may be used for drying alfalfa or other crops to increase the rate of return significantly. The cost of the energy consumed in installation is less than 5% of the energy savings from the first sugar campaign. Installation will require only 11,010 (1.75×10^6 ℓ) equivalent barrels of oil, 360 (57,240 ℓ) for Phase I, 2750 (440×10^3 ℓ) for Phase II and 7900 (1.26×10^6 ℓ) for Phase III.

REFERENCE

1. ERDA Contract EG-77-C-03-1317, "Use of Geothermal Heat for Sugar Refining".

Table 1

Factory Demand	Campaign Equivalent Fuel Demands		Geothermal Phase II Pilot Plant		Geothermal Phase III Retrofit		Geothermal Future Retrofit	
	%	Barrels of Oil	Savings Barrels	Fuel Oil Barrels	Savings Barrels	Fuel Oil Barrels	Savings Barrels	Fuel Oil Barrels
Live Steam to Slicers (1)	2.4	7,730	-	7,730	-	7,730	-	7,730
Turbine Exhaust Steam to Process (2)	11.5	36,240	-	36,240	-	36,240	36,240	-
Throttled Makeup Steam to Process (2)	27.9	88,180	14,700	73,480	88,180	-	88,180	-
Electrical Generation (2)	11.3	35,580	-	35,580	-	35,580	35,580	-
Turbine Mechanical Drives (2)	2.2	6,840	-	6,840	-	6,840	6,840	-
Sugar Cooling Refrigeration (2)	0.9	2,840	-	2,840	-	2,840	2,840	-
Pulp Dryers (1)	43.8	138,350	10,640	127,710	138,350	-	138,350	-
Totals	100.0	315,760	25,340	290,420	226,530	89,230	308,030	7,730

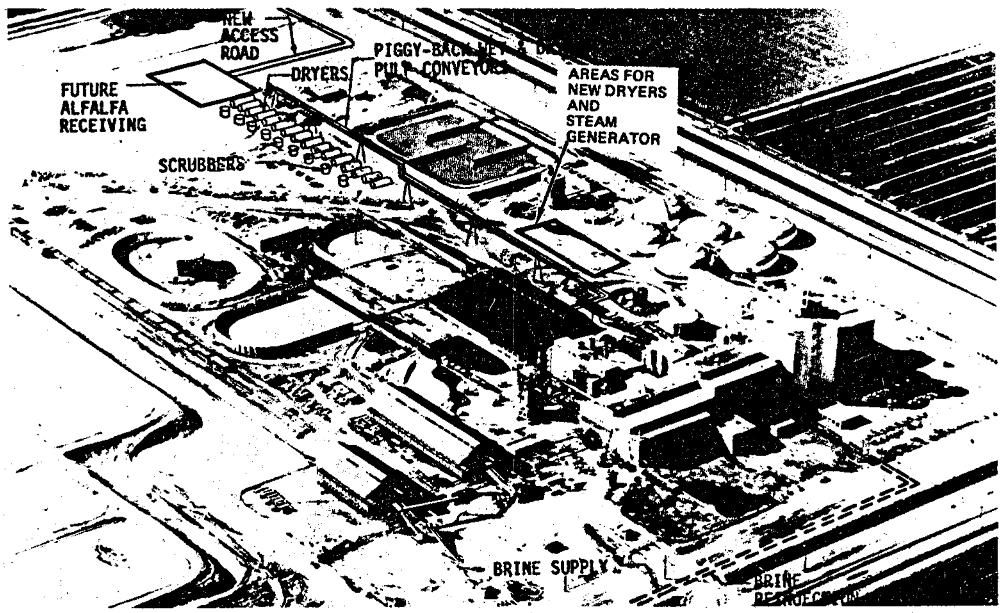


Fig. 1 Modified Holly Sugar facility

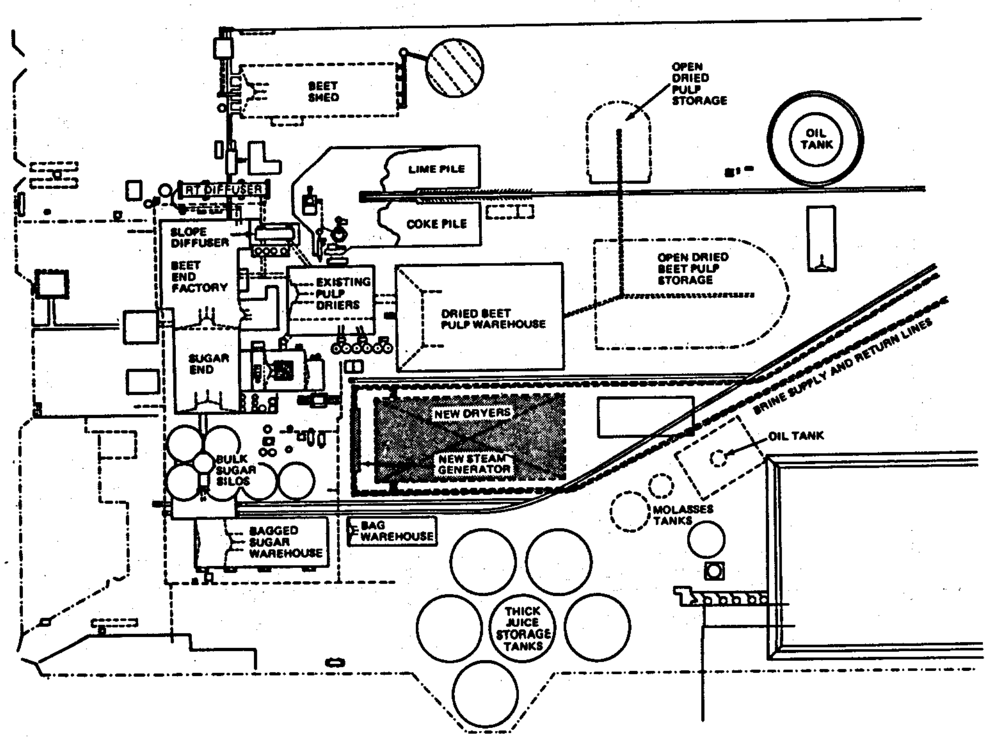


Fig. 2 Holly Sugar Plant (with geothermal retrofit equipment areas)

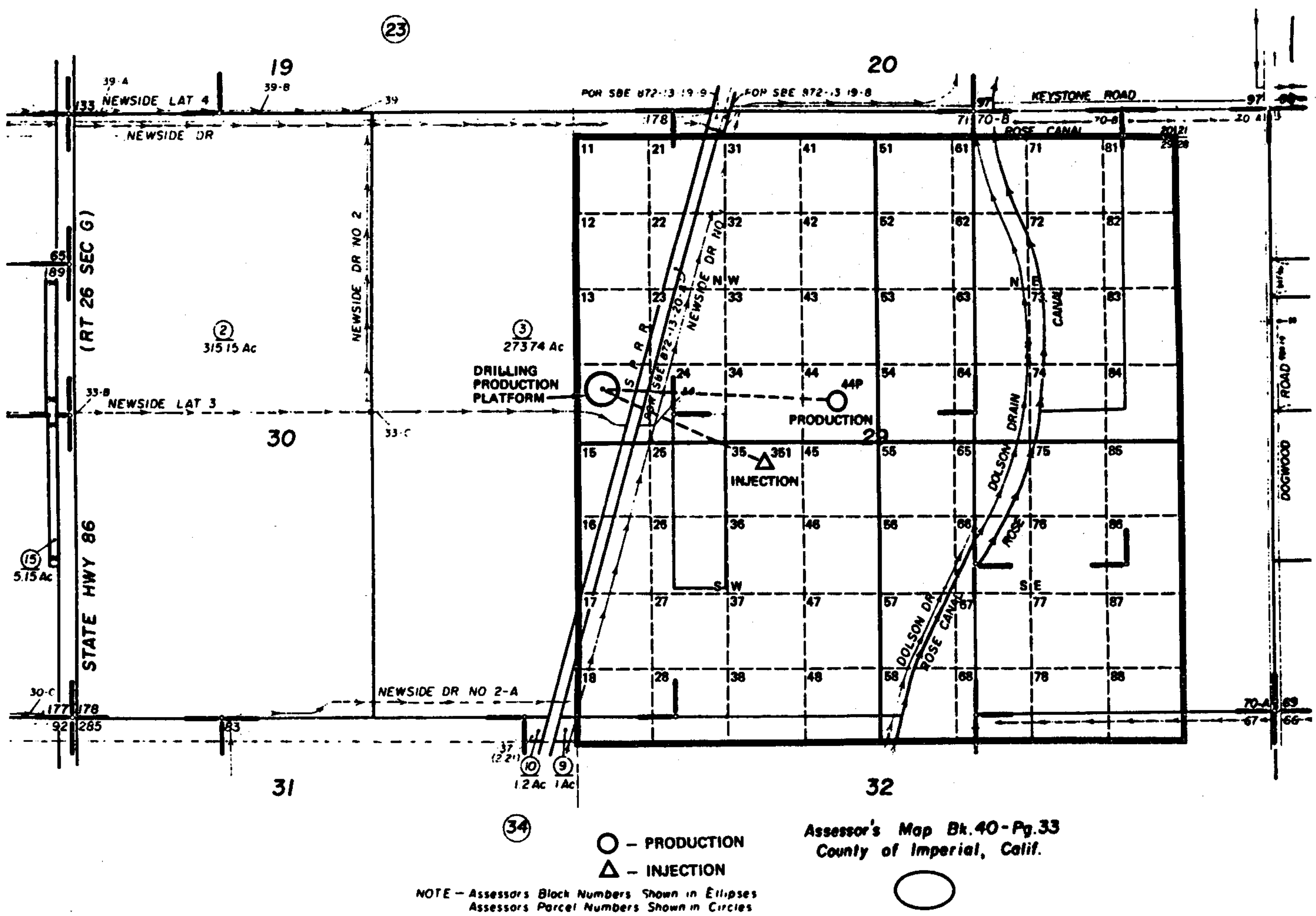


Fig. 3 Location of geothermal wells

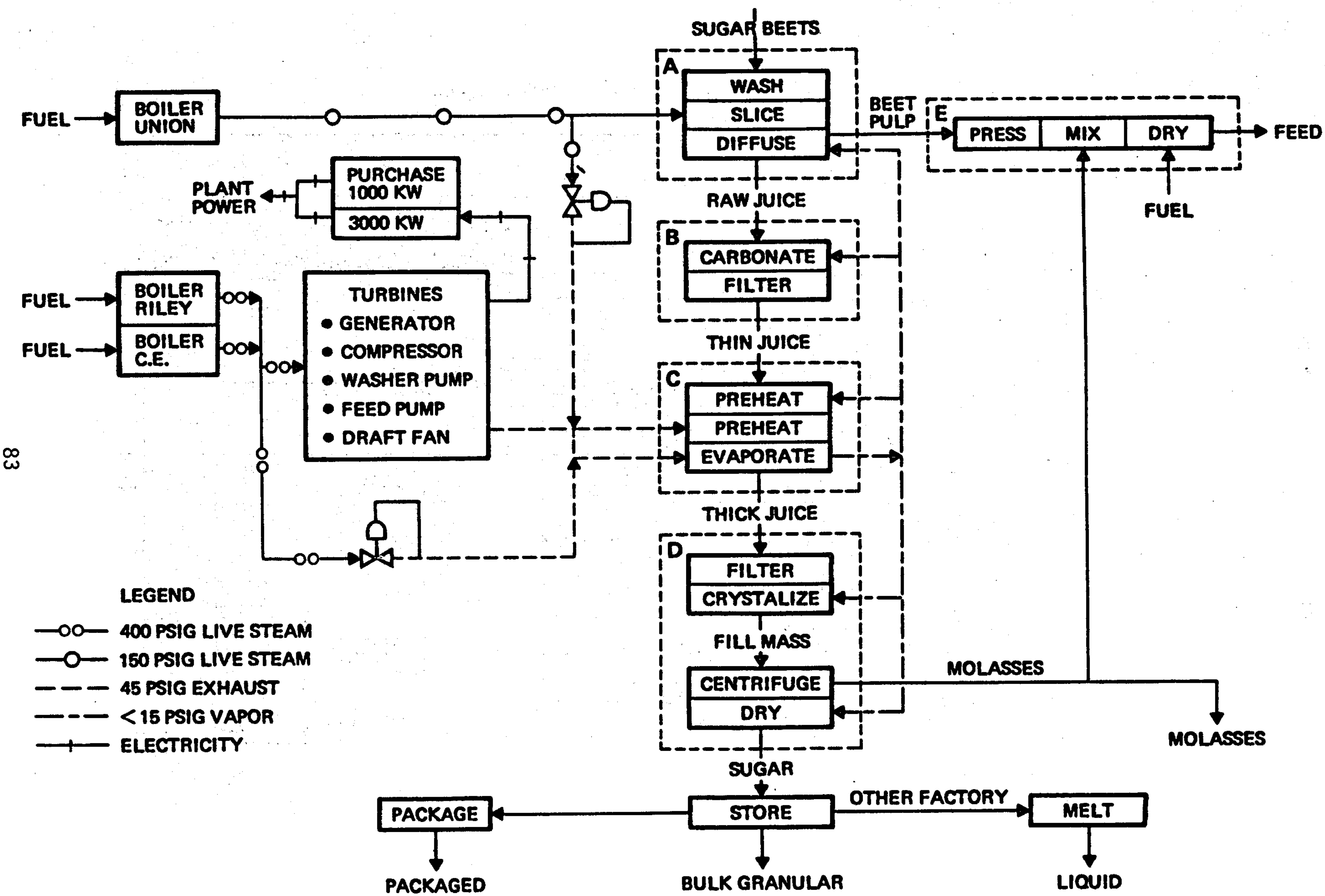


Fig. 4 Holly/Brawley simplified beet sugar processing flow diagram

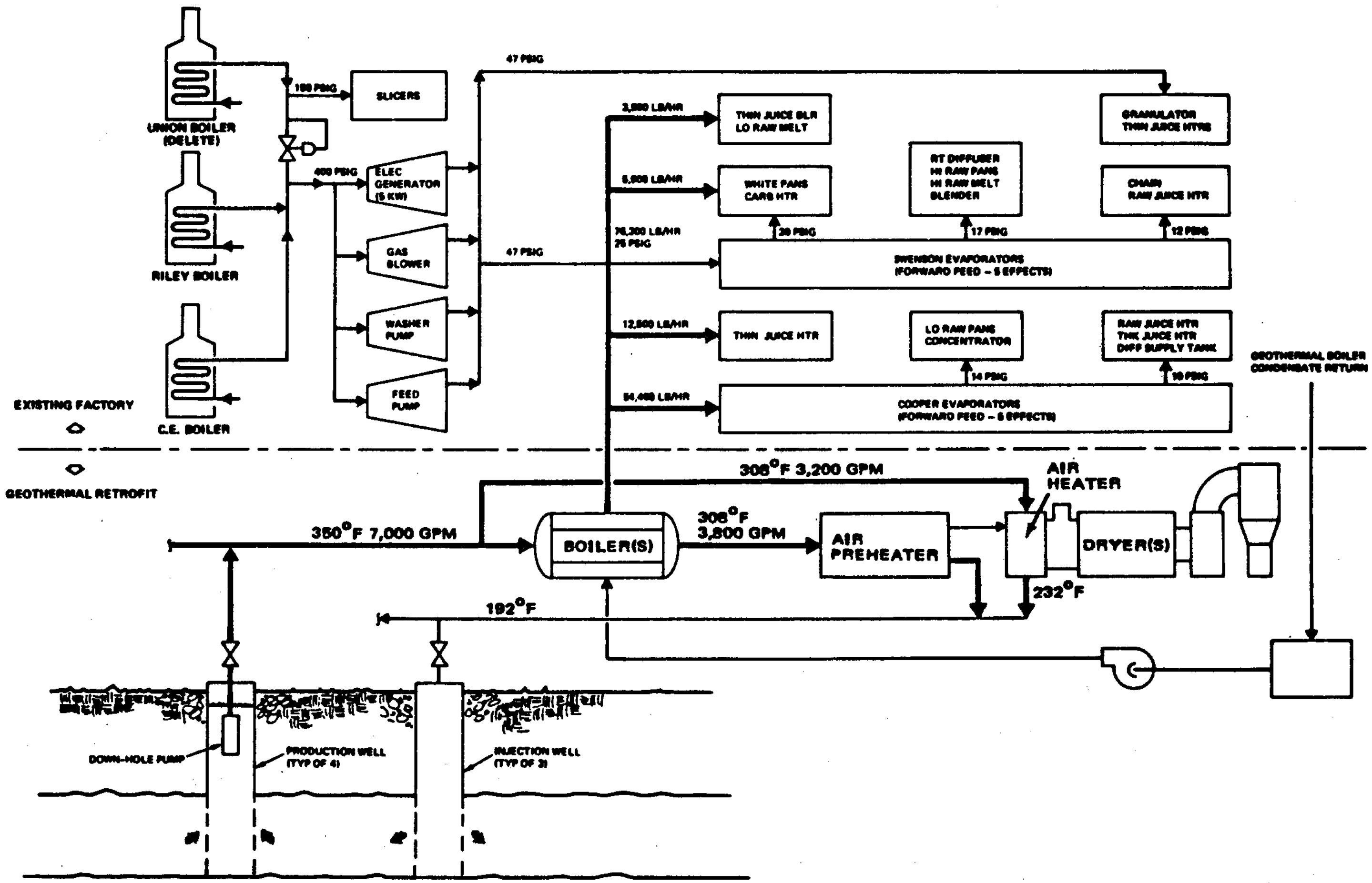
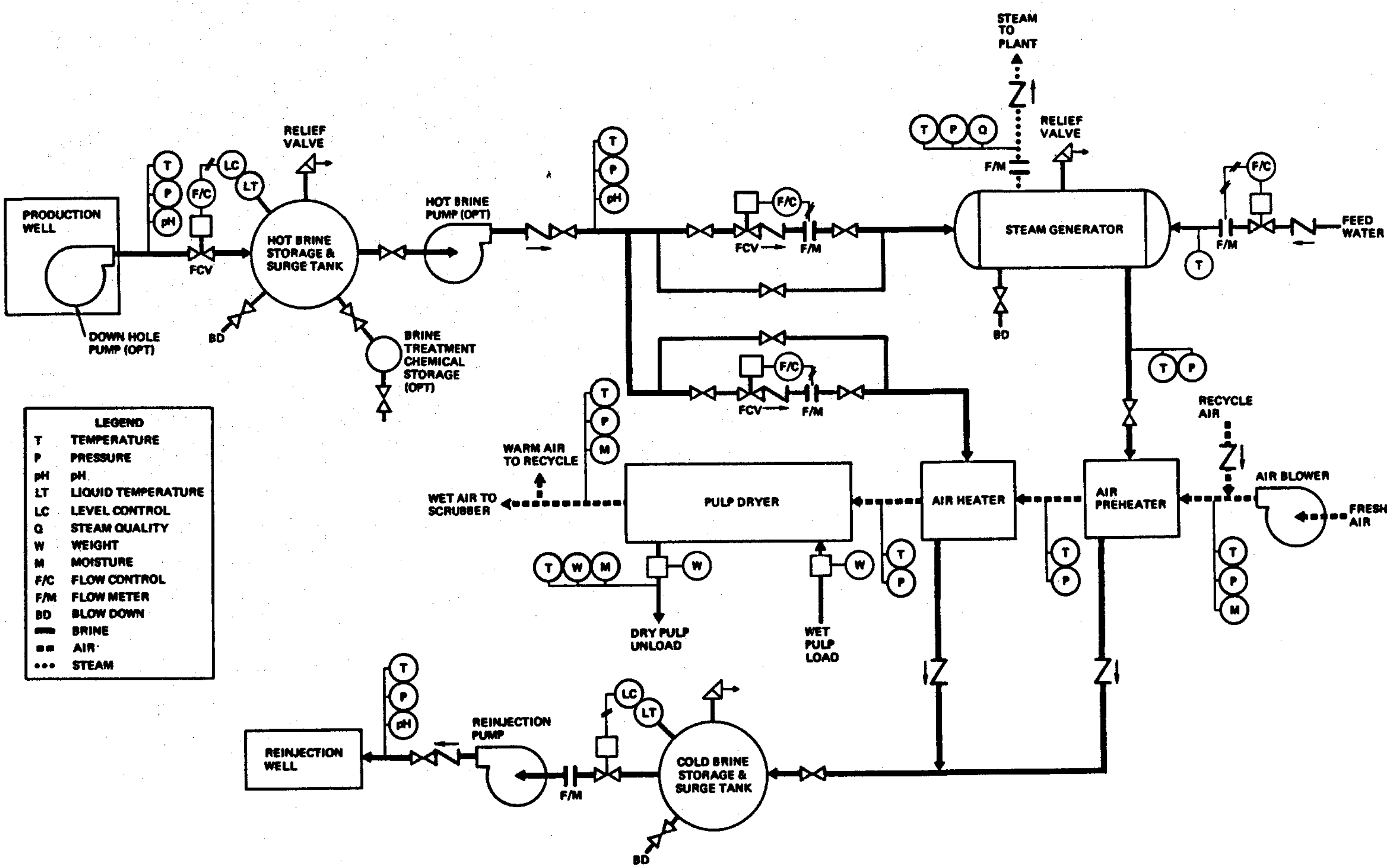


Fig. 5 Geothermal sugar project schematic

PILOT PLANT PRELIMINARY PIPING AND INSTRUMENTATION DIAGRAM



MULTIPLE USE OF GEOTHERMAL ENERGY AT MOANA KGRA, RENO, NEVADA

INTRODUCTION

In this DOE-sponsored program of direct heat applications projects, nine of the twenty two demonstrations are district heating systems, and another seven are for institutional heating.

This emphasis reflects the importance placed on widespread successful use of geothermal energy to replace fossil fuels in the heating of residential and commercial buildings.

However, the vast majority of such use will involve privately-owned buildings, with contracts for heat sale competitively negotiated between users and suppliers. The geothermal suppliers will compete in a market long dominated by conventional fuels.

All but two of the heating demonstrations in this program involve public buildings or institutions. Such projects form ideal demonstrations, with high public visibility and with the advantages of direct participation by local governmental and/or institutional bodies to ease some of the problems of implementation.

But while they are ideal in these respects, they do not, by their very nature, encounter the problems of the marketplace for geothermal energy. They were not intended to do so.

The Reno project was not intended to tackle these problems either. The proposing team included a committed heat user, the owner of a large apartment complex.

This simple picture was attractive as a demonstration because it involved a small and privately-owned geothermal company wishing to establish itself as a commercial developer of geothermal resources for direct applications. Very few such companies exist in this fledgling industry.

It was also attractive because it was almost the only project that involved private residential buildings.

Finally, it was attractive because of its location in the area of a known geothermal resource that has been used for decades on a tiny scale, home-by-home, but has never been developed on a large-scale, planned basis.

Small systems are still being added under the pressure of rapidly rising energy costs. Large-scale projects are finally being discussed, but decisions whether or not to proceed are being held back until it is seen whether this demonstration project succeeds or fails.

If the demonstration is successful, large-scale development of this resource will certainly occur, and the project will have achieved one of the main purposes of this DOE program, in this locality at least.

HISTORY OF THE PROJECT

The simple picture of a pre-arranged demonstration, highlighting a privately-owned residential complex and a commercial geothermal developer, changed when the committed heat user sold the buildings.

The new owner seemed interested, but proved unwilling to accept DOE's wish that the developer of the resource should sell heat at a profit and thus demonstrate the economic viability of commercial geothermal development.

In addition, the existing heating system which was to have been retrofitted, developed extensive leaks.

Accordingly, a new site was chosen and arrangements were concluded with the owners. The demonstration is being executed at Salem Plaza Condominiums, three blocks from the original site.

This change has now been successfully concluded, but it proved far from easy. In the process we learned a great deal about the geothermal marketplace in residential heating, and were forced to face and handle many of the major and minor problems that will arise in widespread commercialization of geothermal direct applications.

Undoubtedly this learning process will continue. More problems will arise and require handling as the project proceeds in this uniquely private and competitive environment. Overcoming these, and the problems we have already handled successfully, all provide critical practical lessons that could only be learned in a project like this one.

Widespread commercialization in the residential and commercial heating market will occur only as a new industry is created out of small companies that are encouraged to enter this field. Such projects are too small to interest major energy companies, and utilities are not structured to take the economic risks that are involved.

SELLING GEOTHERMAL ENERGY TO THE PUBLIC

We have inadvertantly been forced to discover the difficulty of convincing groups of private individuals that conversion of their existing heating systems to geothermal energy is desirable. This has proved difficult even when the conversion is to be made at no cost to them.

The public in Reno is more aware of geothermal energy than the public elsewhere, because so many small systems have operated for decades in southwest Reno. Yet few people there have any precise idea of what components make up a geothermal system, or what wellheads or heat exchangers look like.

Shown an actual system, they are amazed by its simplicity, and the absence of the dragons of their imagination.

Our surveys of the Reno public up to this point have shown that there is definite interest in geothermal development. But there is such a lack of understanding of what it involves, that it is difficult to market without considerable education of potential buyers of geothermal heat.

A background program of broadscale education, and information releases, to the general public will clearly be an important element in achieving widespread commercialization.

For this project we are working successfully with news releases through the largest local TV station and the main newspaper, with items on the conclusion of agreements with the heat users - Salem Plaza Condominiums, a television interview with the President of the Condominium Association, estimates of substantially reduced heating costs for the residents, and a perspective of this project as one of twenty two diversified geothermal demonstrations being sponsored and cost-shared by DOE.

In dealing with the public, the principal fears that have surfaced have been these:

- The noise of drilling may be a serious disturbance over a long period and may provoke complaints and lawsuits from neighboring properties.
- Hot water and steam escaping during drilling, installation, or routine operations may cause large-scale property damage or personal injuries.
- Flooding of neighboring property may provoke lawsuits.
- The geothermal system could damage the existing heating system during the installation, or progressively over time during routine operation.
- Extraction of geothermal water from below the property could produce ground subsidence, and cause major structural damage to the buildings.

The utility that supplies the present natural gas system may cut off that supply, or raise the price, if the gas system is used only as a back-up.
If the well is unsuccessful or the plumbing proves impossible to execute, the developer may walk away leaving a chaotic mess of open trenches and incomplete plumbing to be cleaned up. Lawsuits may follow from unpaid contractors, whose ultimate recourse might be to sue the owners of the buildings.

These fears have forced us to include in our heat sale agreement expensive provisions for insurance, and for performance and completion bonds. Such provisions will typically be required in commercial projects of this kind until education and a geothermal track record have established that many of these fears are groundless or exaggerated.

STRUCTURE OF HEAT SALE AGREEMENTS

Our agreement with Salem Plaza Condominiums has evolved into what may prove typical for this kind of geothermal heating project. It is therefore valuable to review it in some detail.

It is an agreement between a buyer who will use geothermal heat, and a seller who will develop and sell that heat by drilling on or near the buyer's property, and by retrofitting the existing heating system.

With minor changes the agreement would be suitable for the installation of a complete heating system in a new building, instead of a retrofit.

The agreement recites that the buyer owns the property and wants any geothermal resource existing below it to be used in heating the buildings; that the buyer has the right to grant the seller the right to develop a geothermal system and to sell the heat to the buyer.

The seller states that preliminary work indicates that geothermal resources may exist, but that it cannot guarantee they will be suitable for use, or that a geothermal system will in fact be successfully developed.

A series of contingencies are then listed, allowing the seller to explore and develop the resource in steps, with the option at any point to stop if the project appears no longer viable.

Thus, the seller has the opportunity first to confirm the buyer's title to the property and to the geothermal resource estate; then to decide if a well site can be found that warrants drilling; next to decide if the drilling and testing results justify continuing; then to complete the system design and find a disposal method for spent fluids; next to install the system and test it; finally, to run it commercially.

Other contingencies include approval by all governmental and regulatory bodies and (for the specific case of this DOE demonstration) approval of each phase of the operation by DOE, with continued funding of the government part of the cost-shared program.

The buyer then grants the seller the exclusive right to explore and drill for and extract geothermal resources on and from the buyer's property, and grants access and approval to construct the system. Certain areas are specified as off-limits for drilling, and the drilling and construction are confined to 8 am to 6 pm, except in emergencies. Pipelines and power lines are put below ground as far as practicable, and the aesthetic appearance of the property is maintained.

All geothermal resources extracted belong to the seller who makes them available to the buyer up to the buyer's maximum capacity to use them for heating space, domestic hot water, and pools. Any excess may be sold by the seller to others, or used in any way the seller wishes.

The buyer keeps the existing heating system in full repair, operative at all times, and holds the seller harmless from any liability for damages resulting from the seller's failure to deliver heat at any time.

Price of the geothermal heat is set at 15% below the cost of heat derived from natural gas in the buyer's existing system.

The heat measuring equipment is made accessible at reasonable times for the buyer's inspection. Calibration is checked twice a year, or on buyer's request, with the buyer paying for the test if the instrument readings are within 3%. Retroactive adjustments to billing are made if the calibration is off more than 3%.

Monthly meter readings are the basis for monthly bills. If a bill is unpaid for more than 90 days, the seller suspends service, but the buyer remains obligated to pay for heat that could have been supplied during this suspension of service.

After a year's experience, monthly billing changes to a uniform rate based on the average of the preceding twelve months, with annual adjustments to correct for year-to-year variations in the heat used.

Length of the agreement is twenty years, with automatic ten year renewals unless either party gives notice a year before the renewal date. However, after five years, the price is renegotiated.

The seller can assign the agreement, but only if the assignee takes on all the obligations and duties of the seller. The agreement binds successors and assigns.

An arbitration clause covers disputes, and calls for three arbitrators qualified by education, experience and training to handle the particular questions in dispute.

During construction and operation, the seller carries personal injury and property damage insurance of $1 million with the buyer as co-insured, with an additional umbrella policy of $5 million. The buyer maintains its existing $250,000 insurance for boiler explosions and $1 million for property damage and personal injury, naming seller as co-insured.

The seller indemnifies and holds buyer harmless from all liabilities and damage caused in construction; has all construction contractors performance bonded; and additionally carries a performance bond itself to insure no mechanic's liens, and no claims from unpaid workmen, are brought against the buyer.

KEY ELEMENTS OF THE AGREEMENT

Clearly a long term agreement is needed to ensure an adequate return on the capital invested in the geothermal system. Also important is the commitment of the buyer to buy as much heat as he can use from the geothermal seller.

We were unable to avoid a price renegotiation after five years. Firstly, a twenty year commitment seemed unthinkably long to the buyer. Secondly, the possibilities of cheap solar heat or some new, presently unknown, cheap energy source was lurking in the buyer's imagination.

Hopefully, after five years the buyer will be fully addicted to the savings and convenience of the geothermal system; the operating and capital amortization costs will be known more exactly; and a price will be mutually agreed upon without difficulty.

Price proved a key factor in negotiating the agreement. At the buyer's request, we worked with a price structure that pegged the starting price to the current natural gas price, and then escalated it with the Consumer Price Index for All Items Less Energy. As about 40% of operating costs could be electricity used in pumping at a price rising faster than the CPI, this formula would have provided a steadily diminishing return to the seller.

The formula also became unacceptably complex, and was abandoned in favor of the simpler one that was finally agreed upon: 85% of the local natural gas price at the time of billing.

The importance of contingencies in an agreement like this is obvious. Typically, the seller is uncertain of many of the elements required for a successful and economically viable project. The ability to discontinue without penalty is therefore critical, though the buyer must be assured his property will be restored to its original condition if the seller decides to stop in the middle of the project.

The right to sell excess geothermal water to another user, or to supply this buyer with excess from another's property, enables the resource to be developed with some freedom, and to be managed as a reservoir so as to make optimum use of the available energy.

Agreeing to supply 100% of the user's needs was a weakness. It would have been better to supply base load heat to this buyer and to other properties nearby and thus maintain a very high load factor on the geothermal system. But in this first contract we were unable to get agreement to sell excess heat to others unless we committed to supply all of the buyer's needs first. In other contracts, it may be possible to agree only to supply base load heat and to export excess fluids for base load heating elsewhere if the excess exported from a property carries a royalty to the property owner.

Establishing the meaning of price equivalence between geothermal and conventional fuels proved difficult but important. We shall be metering heat delivered to the user's circulating water system; thus efficiency of the geothermal system is not a factor in billing.

A natural gas system, on the other hand, may have an efficiency of 70% or less. Thus a natural gas price of, say, 35 cents per therm could equate with a geothermal price of 50 cents per therm.

Looked at another way, it may only require 70 therms of delivered geothermal heat to produce the same heating as 100 therms of natural gas used in a boiler with an efficiency of 70%.

The point is of considerable importance in making economic evaluations of geothermal systems, and in comparing geothermal costs with costs of fossil fuel systems. There are three factors.

First, some utilities, such as P.G.&E., sell gas at the so-called "Higher Heating Value" which does not take into account the lost heat (about 10%) involved in burning the hydrogen in the gas to water vapor.

Second, and in addition, a newly manufactured and perfectly adjusted natural gas boiler has a theoretical efficiency of only 80%, giving a further loss of 20%.

Finally, in actual use and despite periodic adjustments, there are additional losses of 10% or more, for example from scale build-up (especially where the water is not in a closed circuit and therefore cannot be treated).

Unless these efficiency factors are taken into account, a geothermal supplier may tie his price to natural gas only to find his income is in practice more than 30% below expectations because his system is priced on delivered therms, while the natural gas system is priced on theoretically available therms.

Another critical point is that the buyer agrees to keep his existing heating system in good repair as a permanent back-up in case a geothermal pump fails or some other problem interrupts the geothermal heat supply. The seller is relieved of the responsibility to continually meet the full heating load, and knows that the back-up system will kick in when needed. This proved a critical point in selling geothermal heating in the face of uncertainty about its continuing reliability and the question of whether the reservoir might suddenly be exhausted.

ECONOMICS

The condominiums being heated in this project have insufficient history to determine exactly the heat load for space and water heating at this time.

Operating costs are also very difficult to estimate at this point; but even taking worst case figures, we still find that the operation can provide an attractive profit while giving substantial savings to the condominium owners.

Given a successful well that achieves the expected reservoir temperature and the planned temperature drop in the geothermal system, only a modest flow rate will be needed to supply the condominiums. The excess will be available for neighboring complexes. Serving them could easily double or treble the gross income without adding proportionate increases in operating costs.

Such additional users may be added as part of the demonstration if the budget for Phase II of the project allows this, or may be added as part of the commercial expansion and follow-on to the demonstration at Salem Plaza Condominiums.

TECHNICAL PROGRESS

While the project has been held up by the negotiating of a new heat sale agreement for the new demonstration site, we have completed those steps that could be handled to prepare for moving forward rapidly upon finalization of that agreement.

We have obtained approval of our applications for water rights permits for two wells, extracting a total of 5 second feet.

We have analyzed the structure and hydrogeology of the area in preparation for submission of our Well Site Justification Report, Drilling and Completion Plan, and Well Test Plans. This included detailed photo-geologic interpretation of fault and fracture patterns from the Steamboat Springs area northward through Truckee Meadows to the area of the demonstration.

We have established that the chief environmental concerns are the noise pollution created during drilling operations in this urban setting, and the question of disposal of spent fluids. Satisfactory measures to handle drilling noise have been evolved and proposed, and drilling will be restricted to the hours between 8 am and 6 pm.

Spent fluid disposal alternatives cannot be finally evaluated until our first well provides a sample of the geothermal fluid and an opportunity to confirm its chemistry is benign, and similar to fluids from nearby geothermal wells. If we are able to devise agreeable methods to avoid reinjection, we shall greatly improve the simplicity of the system and its economics. No existing users of the geothermal resource in this area have ever reinjected spent fluids.

In our environmental monitoring program, we have developed a plan to monitor water levels in appropriately located wells, and to establish whether any ground subsidence develops by periodically running leveling lines across the development zone.

PROJECT SCHEDULE

Our original scheduling for the completion of the various work tasks has been modified by the conditions encountered in the geothermal marketplace. Fortunately this has proven time well-spent, not only for the immediate purposes of this demonstration, as a model for handling other potential users should Phase II funding allow expansion of this project, but also for the invaluable object lessons provided for others contemplating similar commercial projects.

Despite the delay, sufficient momentum has been established in other work tasks that completion of Phase I will only be delayed about three months. Drilling should be completed in August, and the system should begin operations in January, 1981.

The area around the demonstration has been undergoing rapid build-out and is now one of the most concentrated zones of residential space in Reno. It forms an increasingly ideal target for large-scale district heating provided this demonstration succeeds in showing that geothermal energy really can be sold to the public for use in large residential complexes, and that geothermal development and retrofitting are technically and economically feasible in this area, and have been carried out successfully.

Dr. David J. Atkinson
Hydrothermal Energy Corporation

SUSANVILLE ENERGY PROJECT

DIRECT UTILIZATION OF GEOTHERMAL ENERGY

LOCATION - NORTH END OF THE HONEY LAKE VALLEY - LASSEN COUNTY

PROJECT DESCRIPTION

RESOURCE

Location The major portion of the identified resource underlays the Southern section of the City of Susanville. (See Figure I)

Depth/Temperature In the Southern section of the resource area (Suzy 4), the production zone is between 75 m - 22 m, temperatures in the 55°C - 70°C range, temperature reversals take place below 250 m. Producing aquifers are associated with free flowing sediments. In the Northern section of the resource area, the production zone commences at approximately 100 m and temperature reversals have not been evidenced to depths of 275 m. Temperatures in this area range as high as 81°C and the production found in a mildly fractural basalt zone.

Flow Rates To date, no production well has been flowed in excess of 1,137 l/spm for a continuous period.

Professional opinion suggests that production wells should not be developed to exceed these rates for two reasons:

1) The limited depth and extent of the production zone; and,
2) To prevent interference and possible influx of cold water from fresh water aquifers above and below.

Fluid Chemistry There appears to be a difference in water quality between the South and North sections of the production aquifer. It is possible, due to the high porosity associated with the South section, that some mixing is taking place; hence, diluting fluids from the production aquifer.

WATER QUALITY ANALYSIS

	NORTH SECTION PPM	SOUTH SECTION PPM
T.D.S.	825	558
E.C.	1,120	1,070
C.A.	26	24
K	9	4.6
Mg	2	16
Na	430	140
Cl	120	64
SO_4	320	190
BiCarb	34	Not Analyzed
CO_3	0	1
Ph	8.1	7.87
B	0.002	1.4

DESIGN

Piping Layout and Design Features   The proposed layout of the geothermal supply pipe line is shown on Figure 1. Table I depicts the buildings to be retrofitted and Table II identifies the various retrofit options for these buildings. Figure 2 shows climatological data for Susanville, Figures 3, 4 and 6 show proposed approaches for modification of various existing heating systems, and Figure 5 shows the comparison of heat pump and fossil fuel boiler.

Unique Features   The displacement of fossil fuels by a renewable geothermal source for space heating and the use of residual heat from the heating district as a tool for economic development by cascading through a park of commerce for commercial use.

System Economics   A preliminary economic analysis of the project has been conducted that would indicate a selling price of $5.00 per million Btu for geothermal energy. No cost of money was considered and the following criteria utilized:

1) Depreciation -

Pumps and equipment	10 years
Wells	20 years
Pipeline, etc.	30 years

2) Normal administrative and maintenance cost
3) Electrical cost of 4¢/Kwh
4) A commercial A & E cost charged in proportion to the depreciation at 30% of capital cost
5) Two production wells producing 1,137 l/s pm @ 30° T
6) Load factor of 40%
7) Well temperature of 76°C
8) Oil price of $7.14 per million Btu

If one then charges geothermal energy to the retrofitted buildings at $5.00 per million Btu, it is possible to obtain a payback on the retrofit cost (without allowing for cost of money) within a 9-year period.

It is evident from the above that by custom-designing a cascading system to utilize the effluent fluids from a heating district, the economics of the system are dramatically enhanced.

Where a charge for money is to be incorporated, special financing systems would have to be developed to assist such programs in the initial years.

It is projected that some 568,000 l/s of fossil fuel will be displaced annually by geothermal energy in the heating district.

STATUS

Technical Scope   To develop two production wells each capable of 1,137 l/s pm at 70°C anticipated not to exceed 275 m in depth and requiring 25 cm - 30 cm casing cemented to prevent fresh water intrusion at 100 m. Injection will take place via a single reinjection well situated in an area outside the main production zone.

Production from the two production wells will pass into a 113,700 l/s surge tank and be distributed to the main line via a transfer pump into a distribution system consisting of approximately 2,350 m of insulated 15 cm - 20 cm main line with approximately 1,850 m of return line consisting of 10 cm - 15 cm uninsulated transite. Fourteen public buildings along the route of the transmission line are to be retrofitted. (See Table I)

Planning to eventually utilize the return effluent fluids from the heating district in a park of commerce is concurrent with the anticipated DOE funded construction phase. This effort is being carried out by the City of Susanville.

The originally proposed scope of the project envisioned three production wells, two injection wells and a distribution system encompassing at least 17 public buildings. The major reasons for a cutback in anticipated scope arose from an enormous escalation in component cost due to inflation and the unanticipated high cost of retrofitting existing heating systems; particularly the low pressure steam systems that became apparent only through the design and engineering effort conducted in Phase I of the DOE Contract.

TABLE I

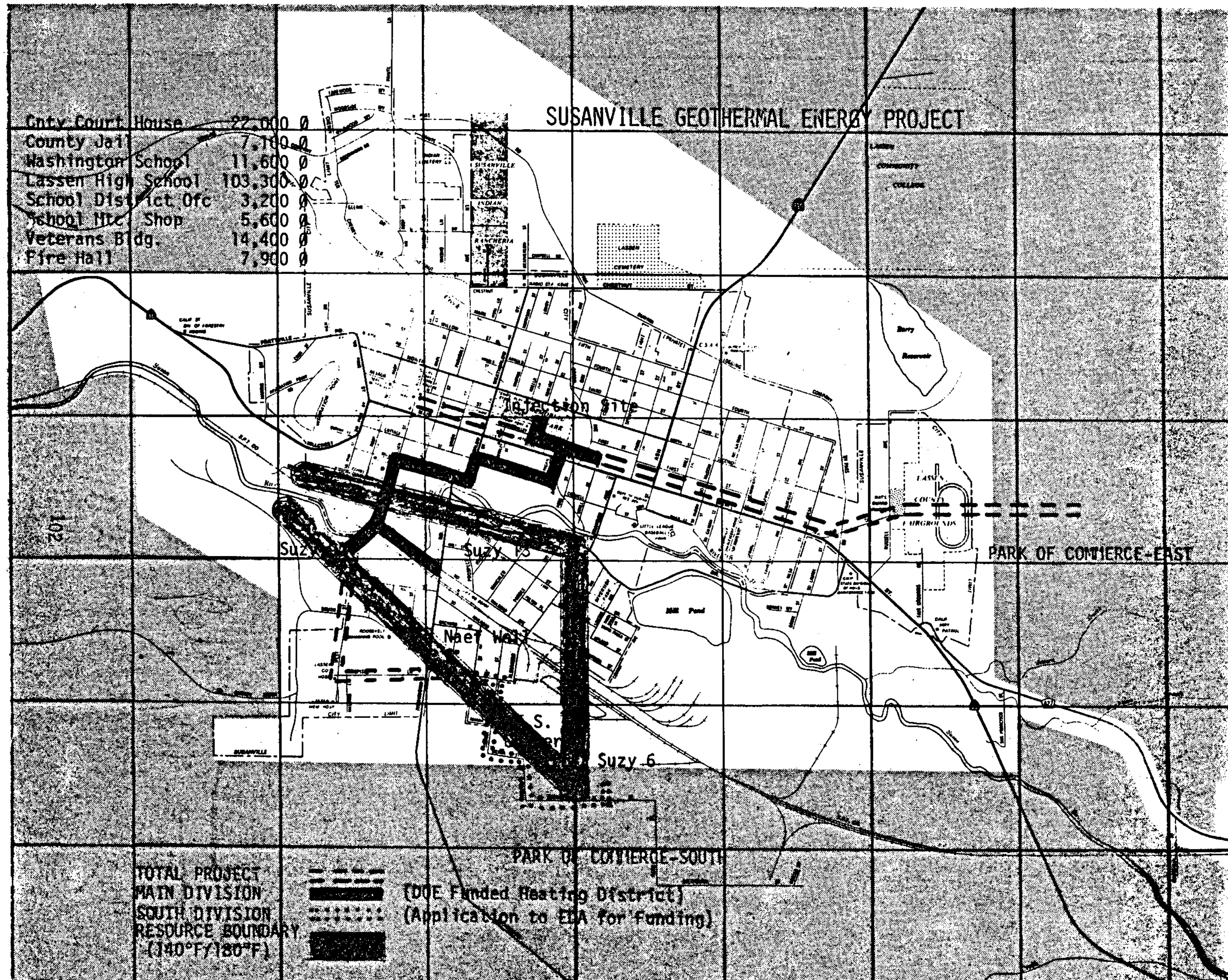
SUSANVILLE PUBLIC BUILDINGS

	SIZE SQ FT	YEARLY FUEL CONSUM GAL	TOTAL HEAT LOAD 10^6 BTU/HR	PERCENT GEO CONVERS %	GEO FLOW GPM
COUNTY COURT HOUSE	22,000	10,300	1.26	32	24
CITY AND COUNTY JAIL	7,100	7,700	.37	100	36
WASHINGTON SCHOOL	11,600	7,200	1.56	100	67
LASSEN HIGH SCHOOL	139,000	114,500	7.23	66	340
SCHOOL OFFICE	3,200	4,000	.21	100	11
SCHOOL MTC. SHOP	5,000	9,520	.76	74	28
VETERANS BLDG.	14,400	7,500	.6	67	20
FIRE HALL	7,900	8,000	.36	100	40
TOTAL	210,200	168,720	12.35	80	566

TABLE II

SUSANVILLE PUBLIC BUILDING CONVERSIONS

BUILDINGS	RADIANT FLOOR PIPES DIRECT ATTACH THRU HEAT EXCH	PROPANE CEILING UNITS REPLACE W/HOT WATER UNITS	HOT WATER FORCED AIR ADD HOT WATER COILS	DIR FIRED FORCED AIR ADD HOT WATER COILS	STEAM-WATER FORC AIR DIRECT ATTACH OR HEAT PUMP AUGMENTATION	STEAM RADIATOR REPL W/ CONVECTORS OR HEAT PUMP
CO. COURT HOUSE						X
CITY & CO. JAIL			X			
WASHINGTON SCH.	X					
LASSEN HIGH (7 Bldgs)					X	
SCHOOL OFFICE				X		
SCHOOL MTC SHOP		X				
VETERANS BLDG.						X
FIRE HALL			X			


SUSANVILLE GEOTHERMAL ENERGY PROJECT
Cnty Court House 22,000 Ø
County Jail 7,100 Ø
Washington School 11,600 Ø
Lassen High School 103,300 Ø
School District Ofc 3,200 Ø
School Mtc. Shop 5,600 Ø
Veterans Bldg. 14,400 Ø
Fire Hall 7,900 Ø
Injection Site
Suzy 5
Suzy
Naef Well
S.
Suzy 6
PARK OF COMMERCE-EAST
PARK OF COMMERCE-SOUTH
TOTAL PROJECT
MAIN DIVISION (DOE Funded Heating District)
SOUTH DIVISION (Application to EDA for Funding)
RESOURCE BOUNDARY (140°F/180°F)
SUSANVILLE
INDIAN
RANCHERIA
LASSEN COUNTY FAIRGROUNDS
LASSEN COMMUNITY COLLEGE

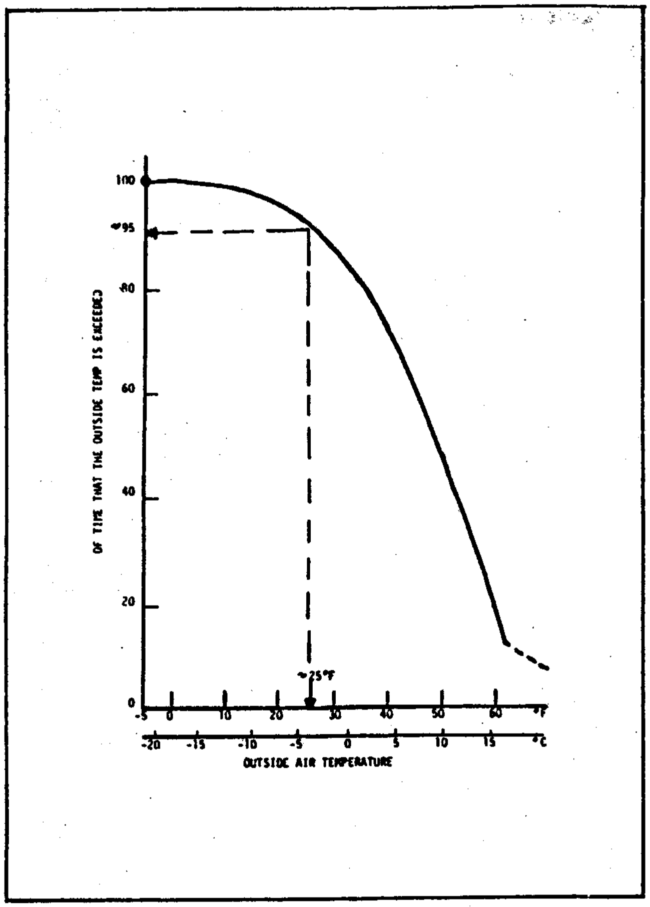


Fig. 2 Susanville climatological data

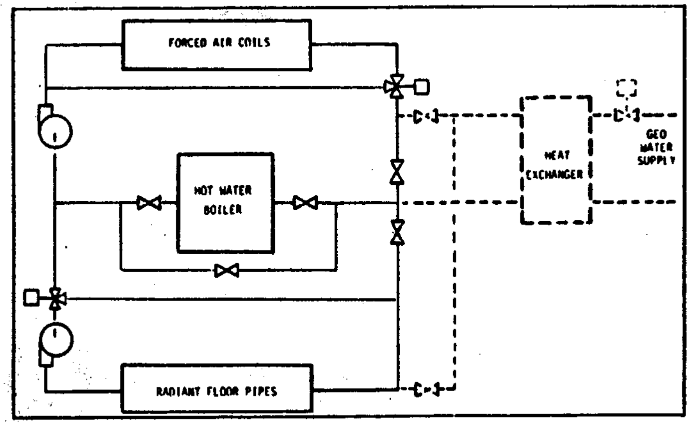


Fig. 3 Modification for radiant heating system

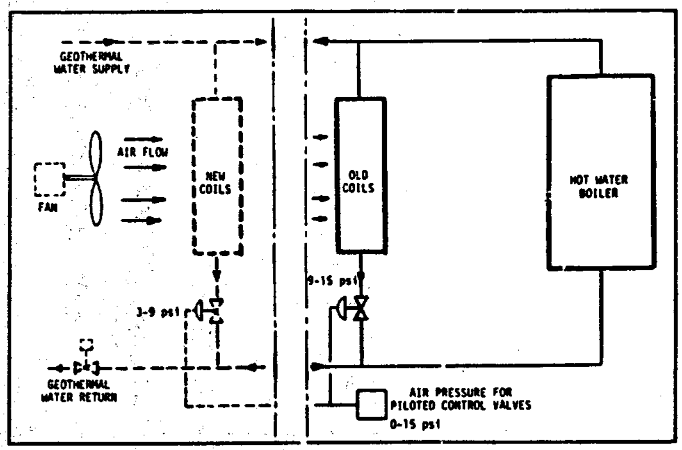


Fig. 4 Modification for forced air coils

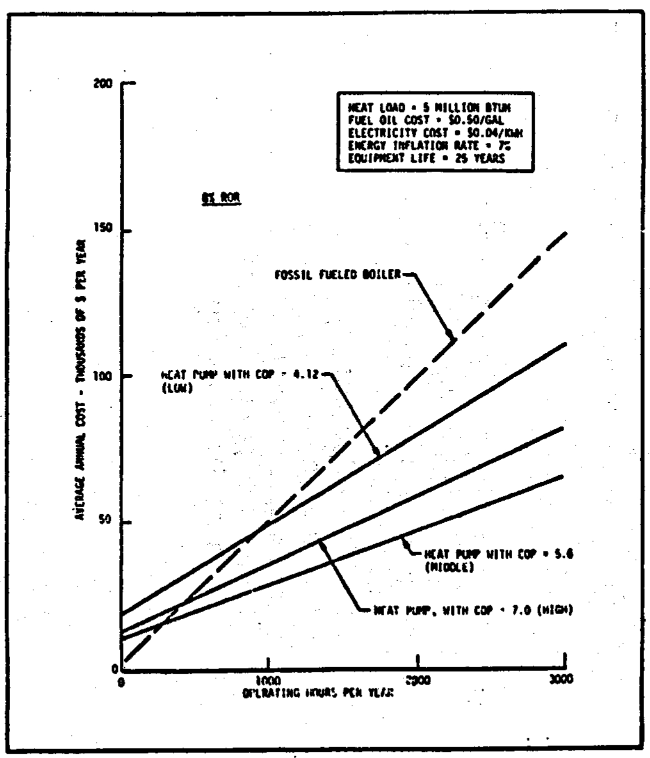


Fig. 5 Comparison of heat pump and fossil fueled boiler

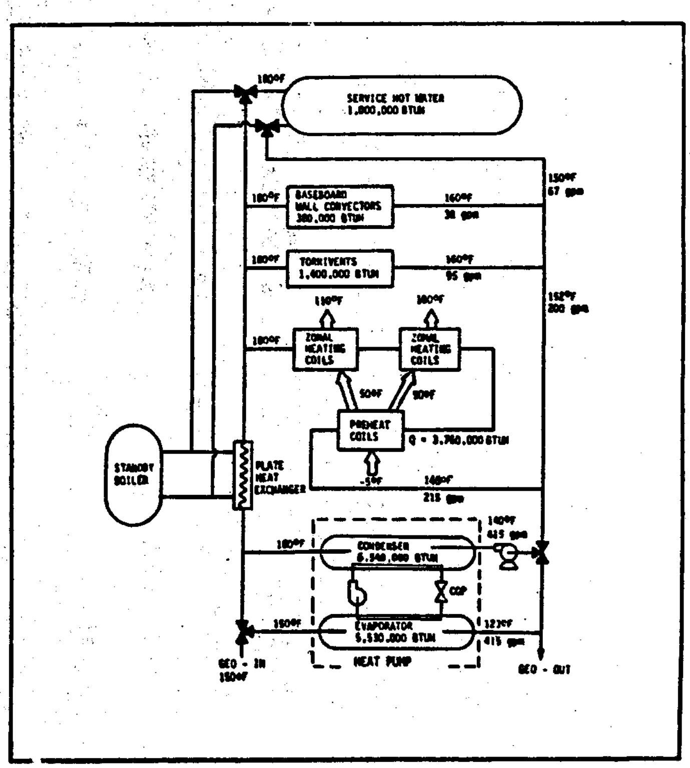
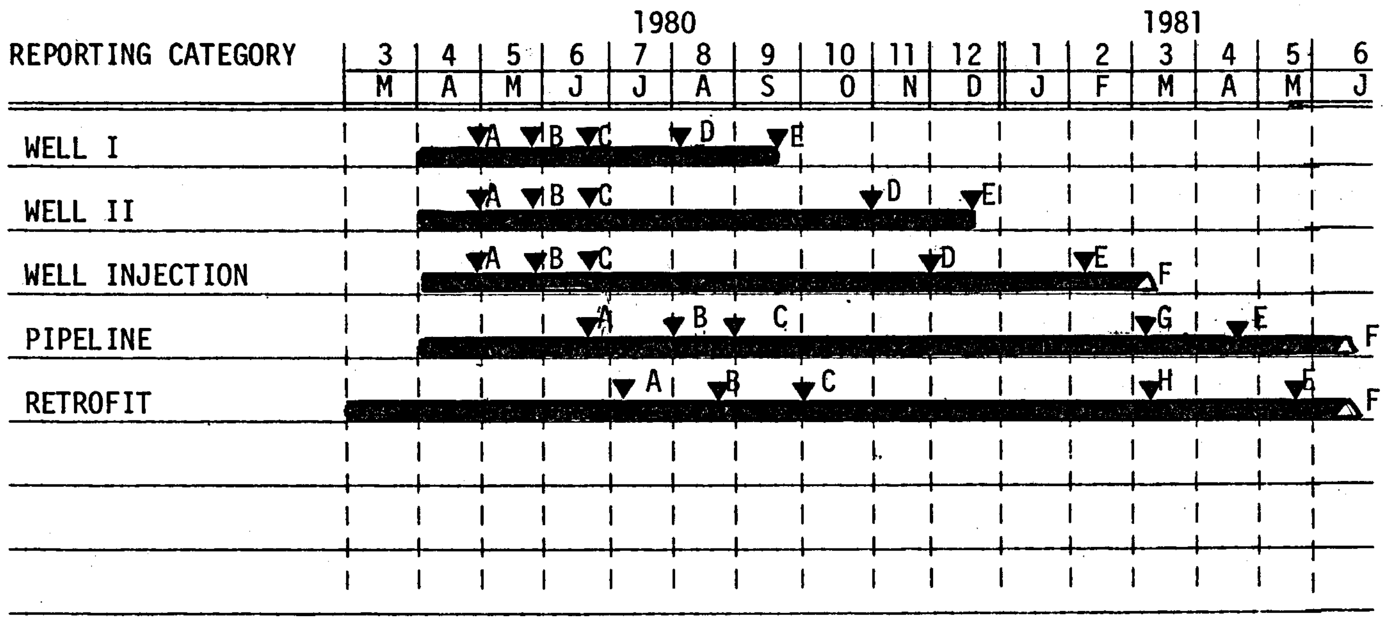


Fig. 6 Modification for additon of heat pump

PHASE II

MILESTONE SCHEDULE



A - Plans, Specs, Eng. Est.
B - Bid Pkg. Ready to Advertise
C - Bids Received
D - Drilling Complete
E - Testing Complete
F - Contract Complete
G - Pumps & Pipeline Complete
H - Tie into Distribution

Schedule The Phase I effort was anticipated to have been concluded by March 15, 1980, and now programmed to be completed by April 30, 1980. The delay has occurred mainly due to the delay in receiving information from LBL on the work done by the Bureau of Reclamation to establish the magnitude and value of the resource. This delay impacted design and engineering effort to a degree. The construction phase is not expected to be impacted unless delays occur in the Phase II negotiations currently under way.

Costs The original proposal anticipated that at least 17 public buildings and associated distribution lines, resource development and associated software efforts could be accomplished for $2,372,378.

Due to cutbacks, escalating costs and identified higher retrofit costs as a result of the design and engineering effort, it is anticipated that the $1.67 million available for construction will be sufficient for the reduced program outline. $335,203 will have been expended on the Phase I effort.

Cost Share The current (Phase I) cost share ratio is 97.77% DOE and 2.23% City. The Phase II effort is anticipated to be a similar level.

As originally proposed in kind and actual cost contribution for Phase II and III which was condensed to a Phase II effort, it was estimated to have a value of $1,937,418. In contract negotiation with DOE, it has become apparent that in kind participation (unauditable) is not considered but recognized, and only actual auditable expenditure (direct cost) be allowed for cost sharing purposes. Therefore, the anticipated ratio in Phase II will be considerably lower than originally projected.

Areas of over(under) run The current Phase I effort is expected to be concluded within the dollar amount allocated.

Projected costings for Phase II are anticipated to hold true for the presently projected construction period.

LESSONS LEARNED

1) Due to on-going efforts by the Bureau of Reclamation to evaluate the extent and value of the resource area, no site was firmly set for the production well locations at the beginning of the design and engineering effort. From existing privately owned wells in the Southern section of the City, it was established that a design temperature of 64°C would be expedient and well siting in that area. The results of the efforts conducted by the Bureau of Reclamation indicated that in fact a resource temperature of 73°C was feasible and that these temperatures were available in the Northern section of the City. This new evidence caused changes in the design and engineering effort; and consequently, in the project configuration. Subsequently, this was to lead to a time-related overrun in the Phase I effort.

The necessity to identify well location and temperatures at the outset of the design and engineering effort is now recognized.

2) With construction costs escalating at unmanageable levels, a well thought out contingency factor should be allowed at initial proposal level and refined as necessary at contract signing.

3) Proposals to DOE should be carefully appraised to insure that the DOE requirements match those of the State in which the project is to be developed. The City of Susanville has encountered considerable problems in seeking State participation within the program due to the fact that the State requires a no-cost/low-cost conservation effort to be conducted on buildings prior to capital intensive conservations retrofits. The City proposal to DOE did not allow for this - only considering maximum fossil fuel displacement.

4) The City of Susanville conducted a Seminar on low temperature geothermal well drilling to introduce potential contractors to the site specific geology and likely drilling conditions to be encountered within the Susanville resource area. All regional contractors were contacted and the turnout was beyond all expectations. We believe this effort will result in competitive bidding when the contracts are let. The City intends to conduct a geothermal pipeline seminar for the same purpose.

5) Retrofit costs of existing low pressure steam systems, normally associated with older concrete/stone built buildings are difficult to justify.

6) Interagency cooperation could have allowed three major federally funded high density apartment complexes to be geothermally heated within the project area that have been completed in 1979/80 utilizing electricity. DOE has been very supportive of the City's efforts to develop interagency activities; however, other agencies have not responded to this effort. Enormous savings of public funds could be achieved with little effort by other agencies.

7) The necessity to educate industry to the realization that low temperature geothermal resources can be developed and utilized with off-the-shelf technology and hardware supplying a source of clean energy below competitive fuel costs. The utilization of effluent energy from heating districts considerably enhances the financial status of the heating district and should be considered a useful vehicle for economic development in rural areas.

8) A well developed and extensive public relations program utilizing local press, radio and TV media has considerably enhanced the project's status with local decision making bodies and allowed for considerable citizens input.

9) Extensive and careful selection of team members can consistantly enhance the harmony of a project and allows for a relatively large team to work well together. Clear definition of work scope and areas of interface must be established at an early stage and relatively sophisticated team management techniques employed. Regular full team meetings allow for information dissemination by individual team members to the full team and more importantly, allows for a full understanding of the overall program by all participants. This leads to a less fragmented overall approach to the design and engineering effort.

10) A considerable amount of effort is required to research the impacts of mineral rights ownership in low temperature geothermal areas, the necessity, if any, of developing unitization systems and production districts. Available legal advice is extremely conflicting on the whole subject of the status of geothermal energy in California.

11) Pricing policies for energy derived from low temperature resources need researching.

12) Imperative that Principal Investigators maintain a sense of humor at all times!!

Philip A. Edwardes
Principal Investigator

EL CENTRO

GEOTHERMAL ENERGY UTILITY CORE

FIELD EXPERIMENT

Presented
at the

Direct Heat Applications Program Semi-Annual
Review Meeting
April 15, 16, 17 1980
El Centro, California

City of El Centro
1275 Main Street
El Centro, CA 92243

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, CA 92103

1.0 PROJECT DESCRIPTION

The City of El Centro is proposing the development of a geothermal energy utility core field experiment to demonstrate the engineering and economic feasibility of utilizing moderate temperature geothermal heat, on a pilot scale, for space cooling, space heating, and domestic hot water. The proposed facility is located on a 2.75-acre (1.1 hectares) parcel of vacant land owned by the Imperial Irrigation District. It is part of a much larger parcel of IID land in the northeastern corner of the City of El Centro. Geothermal fluid at an anticipated temperature of about 250F (121C) will heat a secondary fluid (water) which will be utilized directly or processed through an absorption chiller, to provide space conditioning and water heating for the El Centro Community Center, a public recreational facility located approximately one-half mile south of the proposed well site.

The geothermal production well will be drilled to 8500 feet (2590 m) and an injection well to 4000 feet (1220 m) at the industrially designated IID property. Once all relevant permits are obtained it is estimated that site preparation, facility construction, the completion and testing of both wells would be finished in approximately 26 weeks. Any environmental impacts requiring mitigation would take place within this period. An operations/evaluation period of 18 months will follow the start up of the geothermal heating and cooling system.

1.1 Geothermal Resource

The geothermal resources of the Imperial Valley are incorporated into six known geothermal resource areas (KGRAs): Salton Sea, Brawley, Heber, East Mesa, Dunes, and Glamis (Figure 1). Four of the KGRAs have been drilled and are considered to be economically viable: Salton Sea, Heber, East Mesa and Brawley. The geothermal reservoir which is the energy source for the El Centro field experiment is located on the periphery of the 13.5 sq mi (35 sq km) Heber KGRA, which is estimated to contain 12.4 percent of the Imperial Valley's total geothermal resources. The area of maximum temperature gradient in the Heber anomaly is centered around the township of Heber, approximately 4.5 mi (7.2 km) south of the City of El Centro.

The prevailing geothermal gradient at the drill site is expected to be in the range of 2.0 to 3.3F (1.1 to 1.8C) per 100 ft (30 m). This is based on data published by the U.S. Geological Survey and the California Division of Mines and Geology, and data gathered by Chevron in the Heber area. The high gradients (>3.0) were only observed at shallow depths of less than 1000 ft (305 m) while lower gradients (around 2.0) prevail at greater depths (Figure 2). Therefore, unless geothermal anomalies are encountered, it is highly probable to find 250F (121C) brine at about 8500 ft (2590 m) and it is moderately probable to find that temperature at about 6500 ft (1980 m).

1.2 Design of Facilities

1.2.1 Plot Plan

A preliminary plot plan of the El Centro hot water/chilled water plant is shown on Figure 3. A concrete pad of approximately 2200 square feet in size will provide a foundation for the mechanical equipment. The equipment located on the pad

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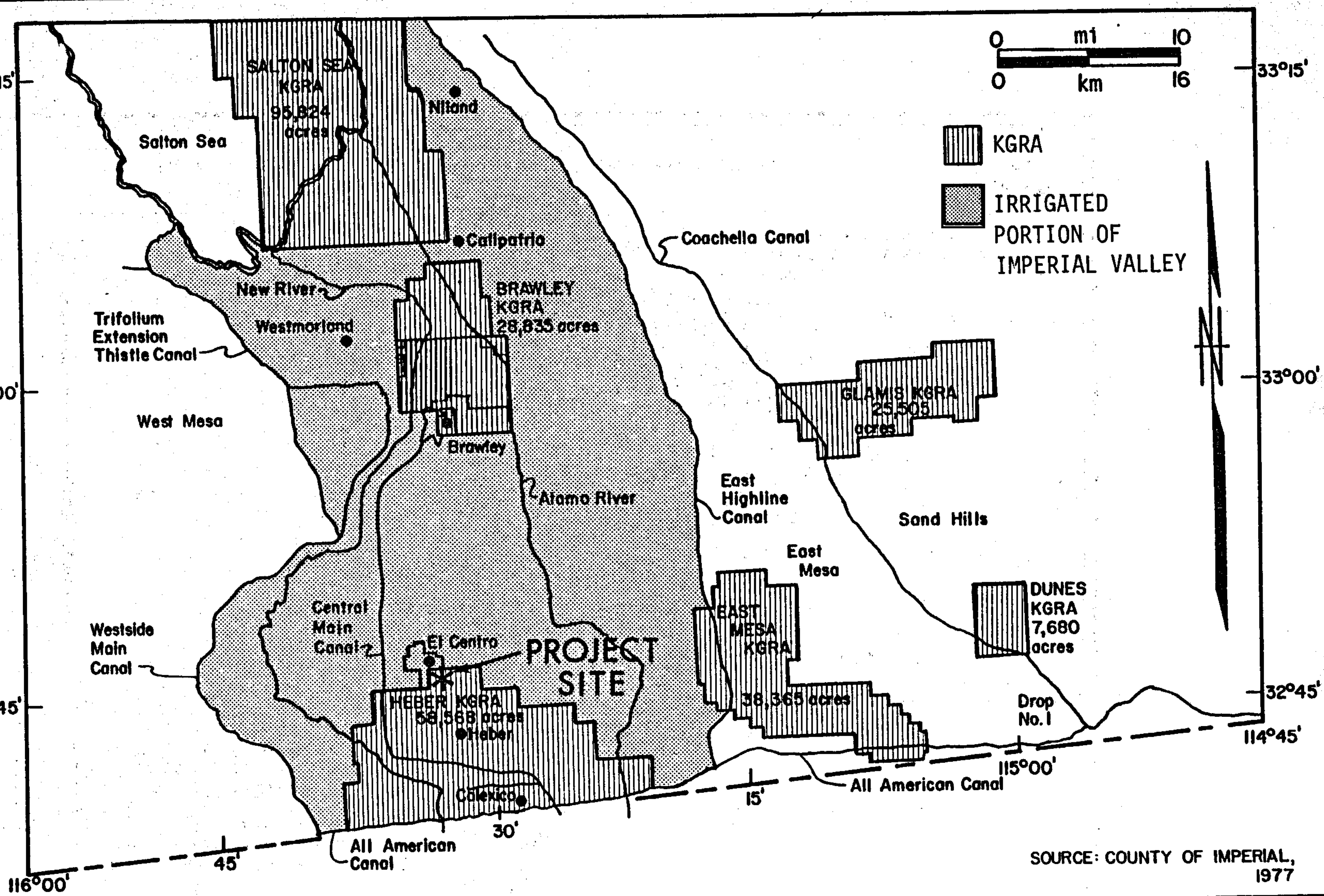

Imperial Valley Known Geothermal Resource Areas (KGRAs)

FIGURE 1

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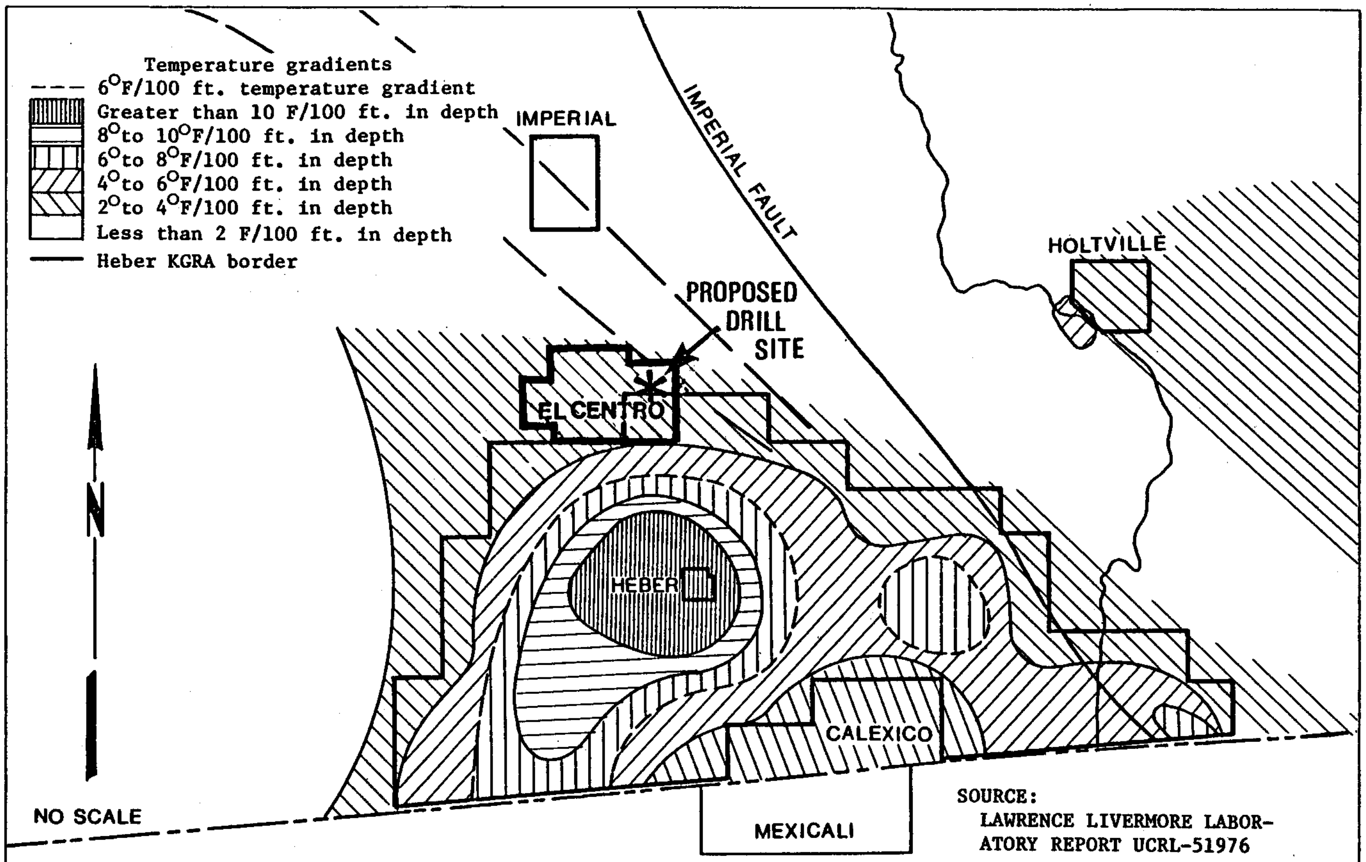

Map of Heber KGRA Showing Pattern of Geothermal Gradients

FIGURE 2

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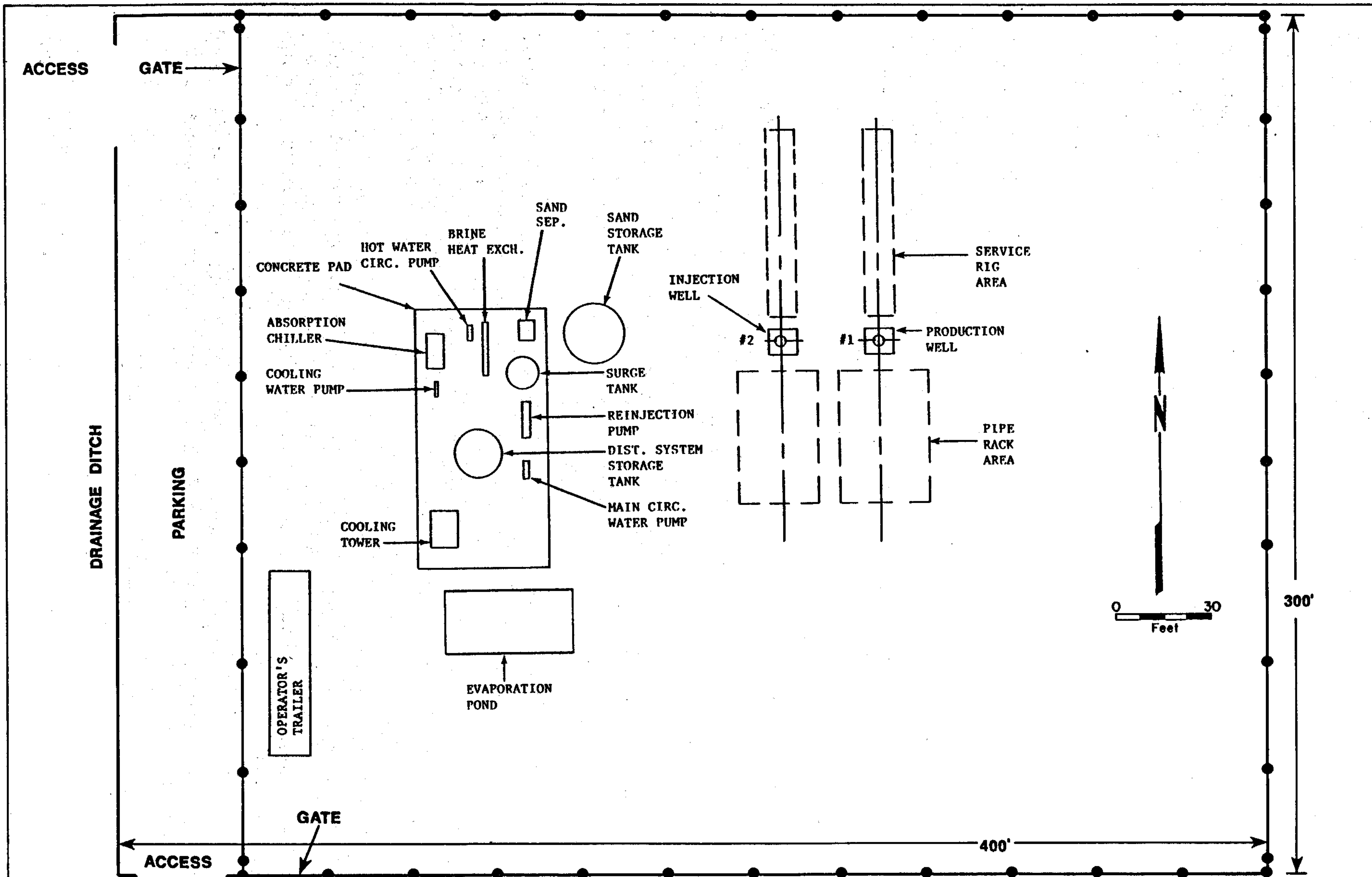

Layout of Facilities at Well Site During Project Operation

FIGURE 3

will include the heat exchangers, the sand separator, a fluid storage tank, absorption chiller unit, cooling tower, and various pumps. Equipment is arranged on the pad for ease of access for maintenance and inspection. A prefabricated steel shade structure will be built over that portion of the pad which requires protection from direct sun and weather elements.

An evaporation pond covering some 1000 square feet will be located adjacent to the equipment pad to handle cooling tower blowdown.

The southwest portion of the site has been reserved for the operator's trailer, visitor's center, and parking lot. Possible access routes to the site are as shown on Figure 4. An entrance at the southwest corner of the site will permit large trucks, semi-truck and trailers to have easy access to the center areas of the site and easy exit by way of the northwest corner. The perimeter of the site will be fenced with a six-foot chain link fence topped with a one-foot barbed wire barrier. The exterior of the site will be landscaped to render the project aesthetically pleasing.

1.2.2 Brine Heat Transfer System

A totally submersible, electric-driven downhole pump, with a setting depth of 500 feet will pressurize the production system to prevent brine flashing. A sand separator will be used to eliminate entrained solids further downstream (see Drawing M-2). A 500 barrel tank will store the solids until they can be disposed of properly. The preliminary design incorporates a counterflow shell and tube heat exchanger of two shell, four pass design to provide the interface between the geothermal fluid and the closed hot water loop. The pipe and valve arrangement allows for the use of both heat exchanger shells in series during full load operation or use of either shell during partial loads or maintenance periods.

A surge tank downstream of the brine heat exchanger will provide positive suction to the reinjection pump. A multistage centrifugal reinjection pump will pressurize the reinjection system to provide adequate flow through the 8-5/8 inch cement cased reinjection well, which will extend to a depth of 4000 feet. A control valve will provide shutoff at the reinjection pump discharge if brine production flow is interrupted for any reason.

Production brine temperature is expected to be 250F with reinjection temperature maintained above 160F. With a downhole pump setting depth of 500 feet, a maximum brine production flow of 730 gpm per well is feasible from this reservoir, however the downhole pump will be sized for a smaller maximum flow suitable for this field experiment.

Temperature, pressure, and flow recorders will provide a permanent record of geothermal fluid production rates and well flow characteristics. All process piping and equipment will be properly insulated.

1.2.3 Chilled Water System

The chilled water system is comprised of an absorption chiller augmented by the hot water loop and the cooling water loop as shown on Drawing M-1. The chilled

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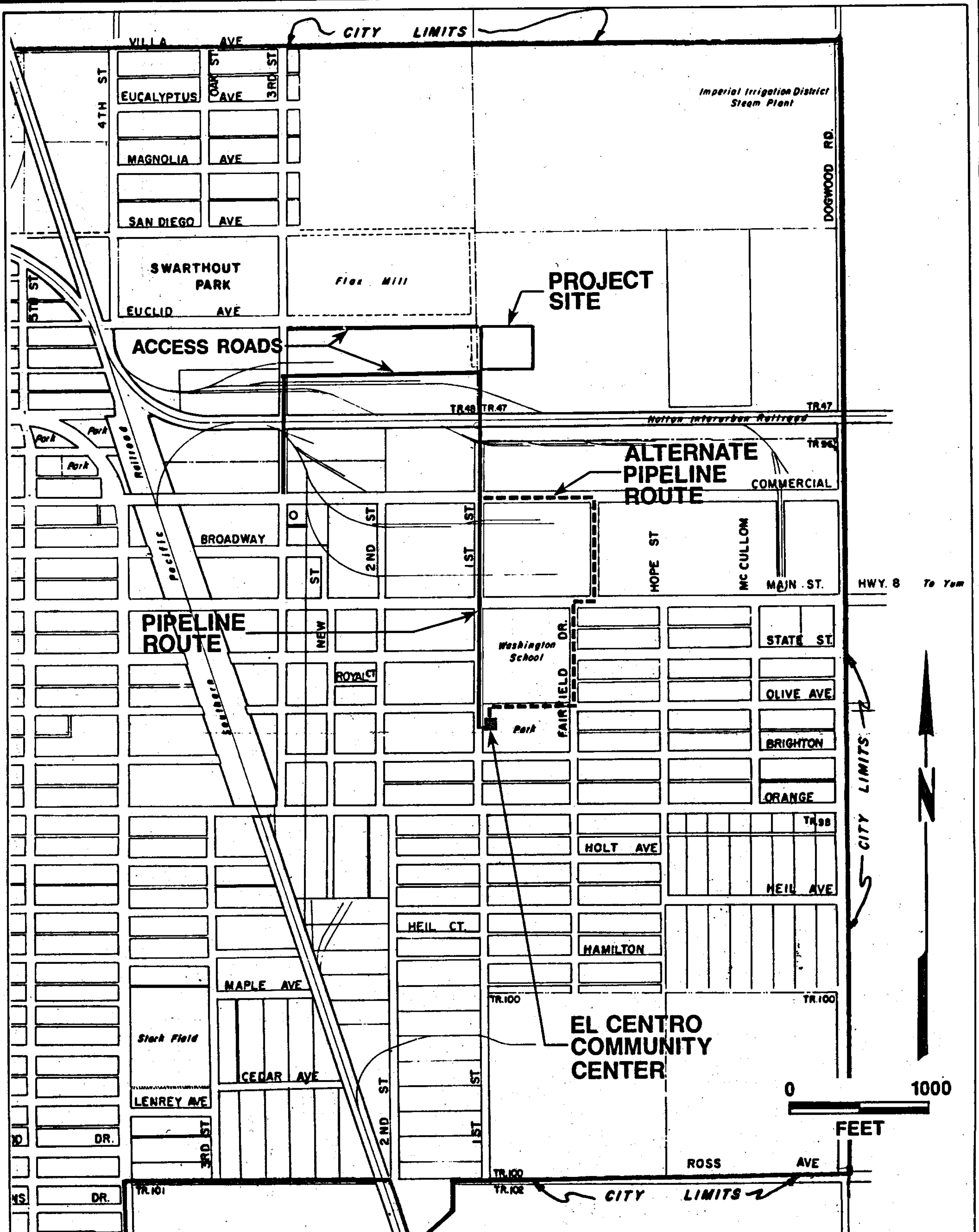
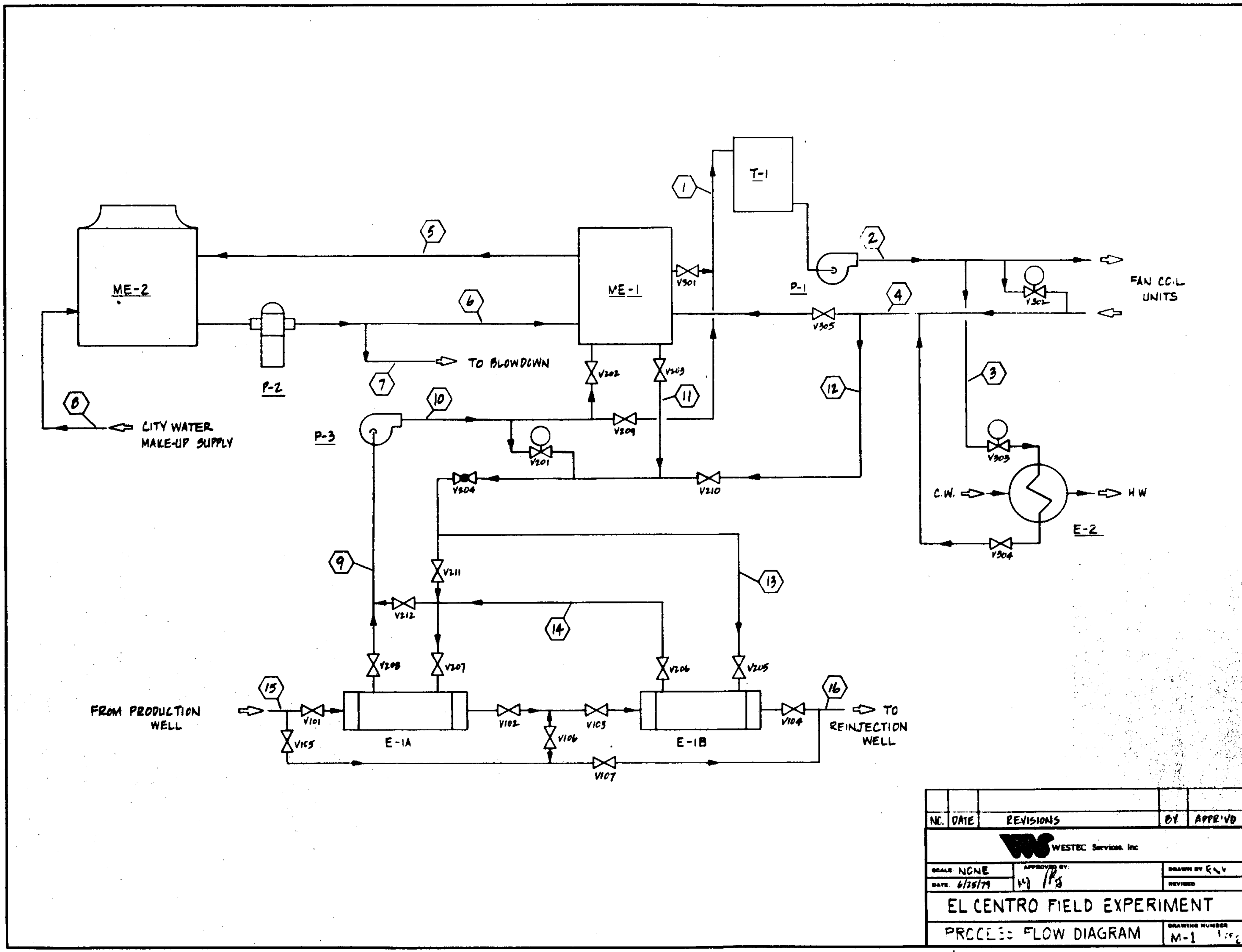


FIGURE 4

Vicinity Map Showing Location of the Project Areas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ME-1
T-1
P-1
P-2
P-3
E-2
E-1A
E-1B
FAN COIL UNITS
TO BLOWDOWN
CITY WATER MAKE-UP SUPPLY
C.W.
H W
FROM PRODUCTION WELL
TO REINJECTION WELL
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V102
V103
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V105
V106
V107
V201
V202
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WESTEC Services, Inc
SCALE NONE
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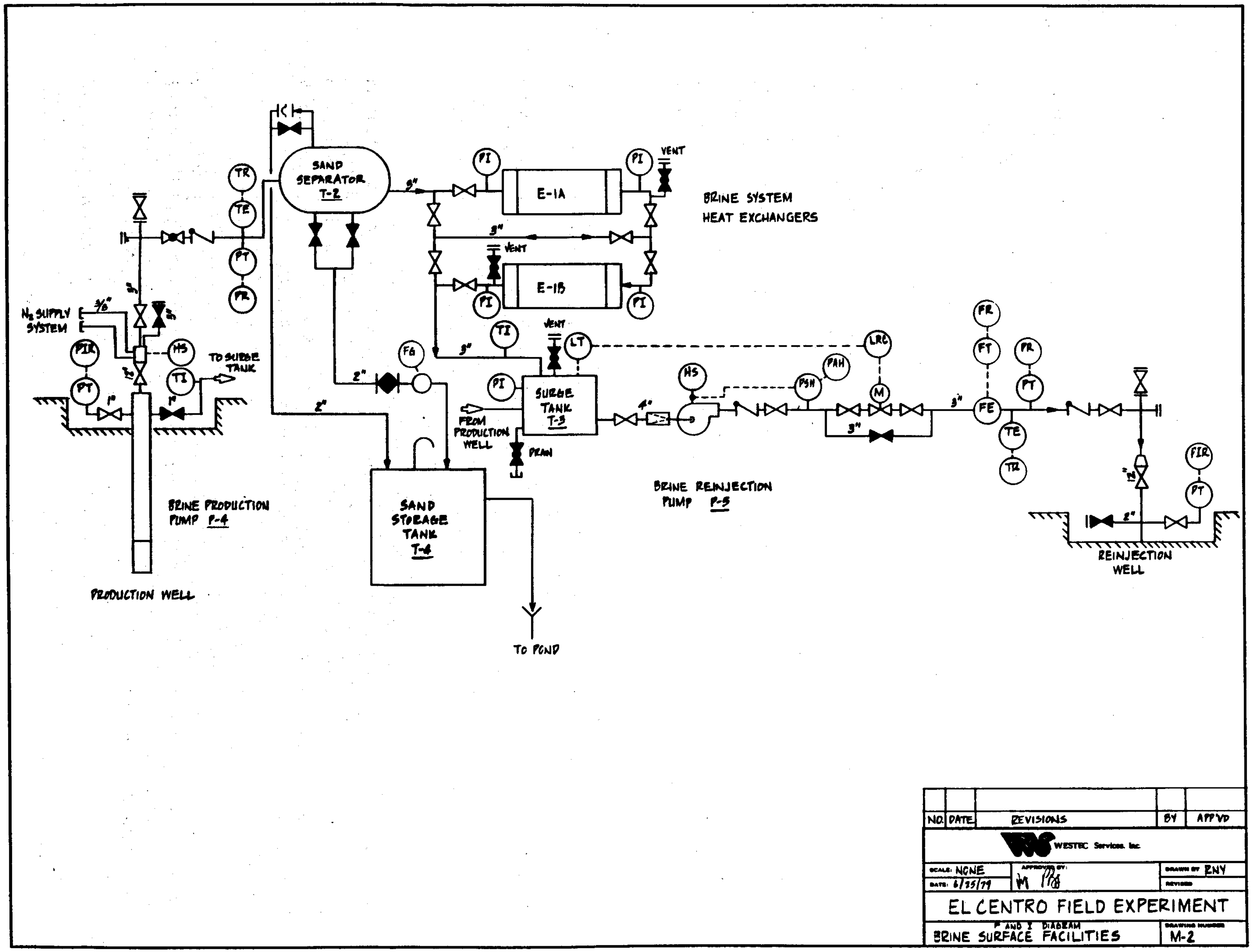
EL CENTRO FIELD EXPERIMENT
PROCESS FLOW DIAGRAM
DRAWING NUMBER
M-1


SAND SEPARATOR T-2
E-1A
E-1B
VENT
BRINE SYSTEM HEAT EXCHANGERS
N2 SUPPLY SYSTEM
TO SURGE TANK
SURGE TANK T-3
FROM PRODUCTION WELL
DRAIN
SAND STORAGE TANK T-4
BRINE PRODUCTION PUMP P-4
PRODUCTION WELL
BRINE REINJECTION PUMP P-5
REINJECTION WELL
TO POND
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BRINE SURFACE FACILITIES
M-2

water system equipment will be located at the pilot plant/well site as described in Section 1.2.1.

The focal point of the chilled water system is the absorption liquid chiller. A lithium bromide-water absorption process was chosen for this field demonstration because commercial units are available that utilize hot water (or steam) to generate chilled water with a minimum amount of electricity required. The lithium bromide-water process has performed exceptionally well during years of field operating experience. Packaged absorption chillers are readily available in various cooling capacities as an off-the-shelf item. Absorption chillers available today can deliver chilled water at temperatures as low as 40F in capacities up to 1660 tons, with appropriate heating and cooling source temperatures. A packaged, single-stage chiller has been chosen for this field experiment. The standard absorption chiller is a closed refrigeration system which operates under a partial vacuum and utilizes water as a refrigerant and lithium bromide as an absorbent in a continuous chemical process. Heat required for the process is supplied in the form of hot water or steam. In addition, the absorption refrigeration system has internal process cooling and heat rejection requirements which must be satisfied by cooling water supplied to internal heat exchangers from a cooling water system. The chiller for this experiment will be sized for 65 ton output capacity using 235F hot water input to the generator. Output from the chiller is designed for 42F chilled water. Auxiliary electrical power is required for the unit circulation pumps.

1.2.4 Hot Water Loop

This closed loop system transfers the heat from the 250F geothermal brine to the absorption chiller during the summer cooling mode. The water in this loop is heated during this mode of operation to 235F in the heat exchangers. An inline process pump maintains hot water flow at 130 gpm and pressurizes the loop to prevent hot water flashing. Hot water flow to the absorption unit is controlled through a bypass line between the hot water supply and return lines which is regulated by a control valve receiving its signal from the chilled water output to the Community Center.

During the winter heating mode this hot water loop transfers the heat from the brine directly to the Community Center. The water in this loop is heated to 195F in the heat exchangers from where it is pumped to the distribution system storage tank, after bypassing the absorption chiller. From this point the hot water is distributed to the Community Center via the distribution system. The hot water from the Community Center returns to the heat exchangers where it is once again heated.

1.2.5 Cooling Water Loop

The major equipment of this system consists of the cooling tower, the circulation pump, and the water treatment equipment. The sole function of the cooling water system is to provide process cooling and heat rejection for the packaged absorption chiller unit.

Evaporation losses, drift losses, and blowdown from the cooling tower will be made up by water from the municipal water system. A ball type float valve will regulate the water level in the cooling tower basin by controlling inflow of makeup water. Cooling tower blowdown will be discharged to an on-site evaporation pond. The solids remaining from the blowdown after dewatering will be collected and transported to an approved solid waste disposal site.

A pump will provide 280 gpm peak cooling water flow between the cooling tower and the absorption chiller.

Water treatment of the cooling water will be accomplished by a timed chemical feed system. Liquid chemicals such as corrosion inhibitors, acid, chlorine, or algaecide will be added to the cooling water as required.

1.2.6 Distribution System

This system utilizes a two-pipe distribution scheme -- one supply pipe and one return pipe providing either hot or chilled water on a seasonal basis. Chilled water is circulated in the system during the summer and hot water is circulated during the winter.

The distribution system loop is made up of a head tank, a circulation pump (both located at the plant site), underground piping to and from the El Centro Community Center, and cooling/heating coils and preheater tank (located at the Community Center). Chilled water will be supplied to the system by means of the absorption chiller unit. Hot water will come directly from the brine transmission system heat exchangers, bypassing the absorption unit.

A centrifugal circulation pump will take suction from a head tank and provide the fluid flow to the Community Center.

1.3 System Economics

A total of approximately 6.02×10^8 Btu/yr of energy presently consumed by the El Centro Community Center is potentially replaceable by geothermal energy. This consumed energy presently provides space heating and cooling and domestic hot water heat for a total load of 8.31×10^8 Btu/yr on the building. For this demonstration, the geothermal hot/chilled water plant will be sized to handle up to 97 percent of this annual load. This means that approximately 2.9×10^5 cubic feet of natural gas and 8.7×10^4 kilowatt hours of electricity could be replaced each year by geothermal energy.

Actual life cycle energy cost savings are not available at this point in the project; however, an initial feasibility study for the Community Center conducted by WESTEC Services in 1979 showed that about $5800 per year could be saved at the Community Center if the Center were part of a large district wide geothermal system. The potential energy cost savings for El Centro lie in a geothermal district heating and cooling system which is tied to large industrial base users.

Over 70 percent of the total energy consumed in the residential and commercial sectors of El Centro is potentially replaceable by geothermal energy. By forming a large base of concentrated geothermal industrial users, geothermal district heating and cooling to the residential and commercial sectors of the City is viable. A geothermal district system in the City of El Centro could replace the equivalent of 115,000 barrels of fuel oil per year (70,000 bbls/yr converted to electricity and the equivalent of 45,000 bbls/yr for heating). The initial feasibility study also showed that in a combined district and industrial park model, between \$3.5 and \$6.5 million per year (in 1977\$) could be saved by the residential and commercial consumers in life cycle costs for space conditioning and water heating purposes. The key to this cost savings is the utilization efficiency of the geothermal fluid, i.e., the extent to which the available geothermal heat energy is continuously used throughout the year. Geothermal district heating and cooling systems utilizing energy cascading techniques with industrial processes could provide this key.

2.0 STATUS

2.1 Technical Scope

The overall objective of this field experiment is to demonstrate the engineering and economic feasibility of the utilization of moderate temperature geothermal heat, on a pilot scale, in the City of El Centro for space cooling, space heating and domestic hot water heating. This field experiment will be utilized as a test bed for evaluating engineering variables essential to the design of cost effective geothermal hot and chilled water distribution systems.

The project plan calls for drilling a geothermal well within the City, building a pilot hot water/chilled water plant at the wellsite, and distributing the hot or chilled water to the El Centro Community Center (located about one-half mile away from the pilot plant). Heat from the brine will be transferred to the working fluid by way of heat exchangers located at the wellsite. City supply water has been selected as the working fluid because of its relatively low cost and availability. The heated City water will be used in the winter to supply space heat and heat for domestic water for the Community Center. During the summer, the heated City water will be used in a lithium bromide/water absorption process to produce chilled water to be used for space cooling the Community Center. The Community Center will be retrofit with heating/cooling coils for the space conditioning requirements.

Key Design Features

Number of Production Wells	One
Number of Injection Wells	One
Type Absorption Chiller	Lithium bromide/Water
Cooling Capacity	101 tons nominal 65 tons available
Hot Water Temperature IN	235F
Hot Water Temperature OUT	215F
Type Heat Exchanger	Shell and Tube
Capacity (max.)	1.2×10^6 Btu/hr
Brine Temperature IN	250F
Brine Temperature OUT	$\geq$ 160F
Hot Water Temperature IN	215F cooling mode 175F heating mode
Hot Water Temperature OUT	235F cooling mode 195F heating mode

The only major technical change from the original conceptual design has been that a two-pipe distribution system will be used instead of the originally proposed four-pipe system. Approximately 97 percent of the entire heating and cooling load for the Community Center can be satisfied by using only two pipes. The remaining 3 percent load is non-seasonal load, i.e., heating required during the summer season and cooling required during the winter season. The added cost of adding two more pipelines to satisfy such a small percentage of the load was deemed to be unjustifiable for this particular demonstration. Existing conventional HVAC equipment can more than make up for this small load at the Community Center.

There are no other changes anticipated in the system at this time.

2.2 Schedule

The prime contract for this project between DOE and the City of El Centro was executed on July 11, 1979. The environmental impact report was certified by the City Council on July 5, 1979. The technical conceptual design was completed on August 3, 1979.

Subsequently, continued public dissension centering on the original drillsite prompted the City Council to consider an alternate drillsite. Thus a second environmental impact report for the new proposed drillsite was prepared and submitted to the City Council, which approved the new site EIR on January 16, 1980. Work related to this site change included negotiating a lease for the site and resolving problems of access and utility service to the new site.

At this time, data is being gathered to support the geothermal resource at the new proposed drillsite. The drilling phase is tentatively set to begin sometime in August 1980. The supply well will be completed within the first 6 weeks in order to permit assessment of project viability before material procurement begins. Assuming initial favorable results from this well, an injection well will be drilled in a 3-week period. Construction of surface facilities will follow. Further tests, equipment installation and injection well completion will consume the remaining portion of the 18-month period allocated for well drilling and construction. Concurrently with installation of improvements at the well site, the necessary equipment will be installed at the Community Center.

An operations-evaluation period of 18 months will follow startup of the system. At the end of the operations-evaluation period, this proposed project will be concluded. During or after this period, the City of El Centro will decide whether to utilize production from the well which is not being used for the Community Center for other direct heat applications.

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DIRECT UTILIZATION OF GEOTHERMAL RESOURCES AT MONROE, UTAH

D. F. Nay, Mayor of Monroe City
R. F. Harrison, Terra Tek
C. K. Blair, Terra Tek
B. J. Sakashita, Terra Tek
A. H. Jones, Terra Tek

For Presentation at the

Direct Heat Applications
Semi-Annual Program Review

April 15, 16, 17, 1980

El Centro, California

ABSTRACT

A district heating scheme was planned for Monroe City, Utah using the Monroe KGRA to provide geothermally-heated water to commercial developers, large buildings, small stores and residences for both space heating and domestic water heating. Preliminary resource assessment estimated maximum resource temperatures of 250°F associated with the Sevier Fault. The fault is fed from a large watershed to the east. In drilling, the maximum bottomhole temperature encountered was 180°F with a wellhead temperature of 165°F. Natural artesian flow was 260 gpm. Based on this low temperature, the low artesian flow rate and the relatively large area per load to be serviced, the proposed district heating system was determined to not be viable. The program is currently under evaluation for redirection.

HISTORICAL PERSPECTIVE

Monroe City is a small central Utah community with a population of 2,000. It is located about 160 miles south of Salt Lake City in the Sevier River Valley to the immediate west of the Sevier Fault. The fault rises to within 2,000 feet of the town's eastern boundary. The Monroe KGRA is situated along this fault and is characterized by two large tufa mounds from which springs discharge up to 380 gallons per minute of warm water.

Mundorff (1970) described the hot springs of the area, furnished analytical data and flow estimates. The dissolved solids concentration of the Monroe Springs discharge was measured at 2,770 ppm with the major constituents being: Silica 54 ppm, Calcium 282, Sodium 562, Bicarbonate 354, Sulphate 898 and Chloride 630. Utilizing this data and the Na-K-Ca geothermometer of Fournier and Truesdell (1973), W. T. Parry calculated the minimum geothermal reservoir temperatures (temperature of last wall rock equilibration) as 387°F and 379°F, respectively. Measured temperatures of the Monroe and Red Hill springs were 149°F and 169°F, respectively.

In the summer of 1977, the University of Utah (Ward, 1977) performed a comprehensive resource assessment of the Monroe KGRA under U.S. Department of Energy funding. This reservoir assessment indicated that maximum possible temperatures of 250°F might be realized at a depth of 1,000 feet. Recharge to the field is provided from drainage from the Sevier River Valley and a large watershed area to the east for which the Sevier Fault serves as a conduit. The University of Utah concluded that the resource was suitable for low-temperature development. Monroe City supported by Terra Tek submitted a proposal in response to PON EG-77-N-03-1553 in November 1977 to develop a district heating system for the City. The city-wide district heating development would be carried out in three phases. Phase I of the proposed program, shown in Figure 1, was to be financed under the PON program. Only part of the city was to be served in this phase. The buildings to be serviced included the South Sevier High School, an elementary school, a junior high school, a Latter Day Saints (LDS) Chapel and seventy three residences for both space heating and domestic water heating.

This report shows the proposed district heating system not to be economically viable due to wellhead temperatures (165°F), which were lower than predicted based on the original resource assessment, the cost of pumping as a result of the low artesian flow, the large area/low density population distribution in Monroe City (see Figure 1) and the high cost of piping the spent geothermal fluid to a distant reinjection site (required by the Utah Water Pollution Committee). The program is currently under evaluation for redirection.

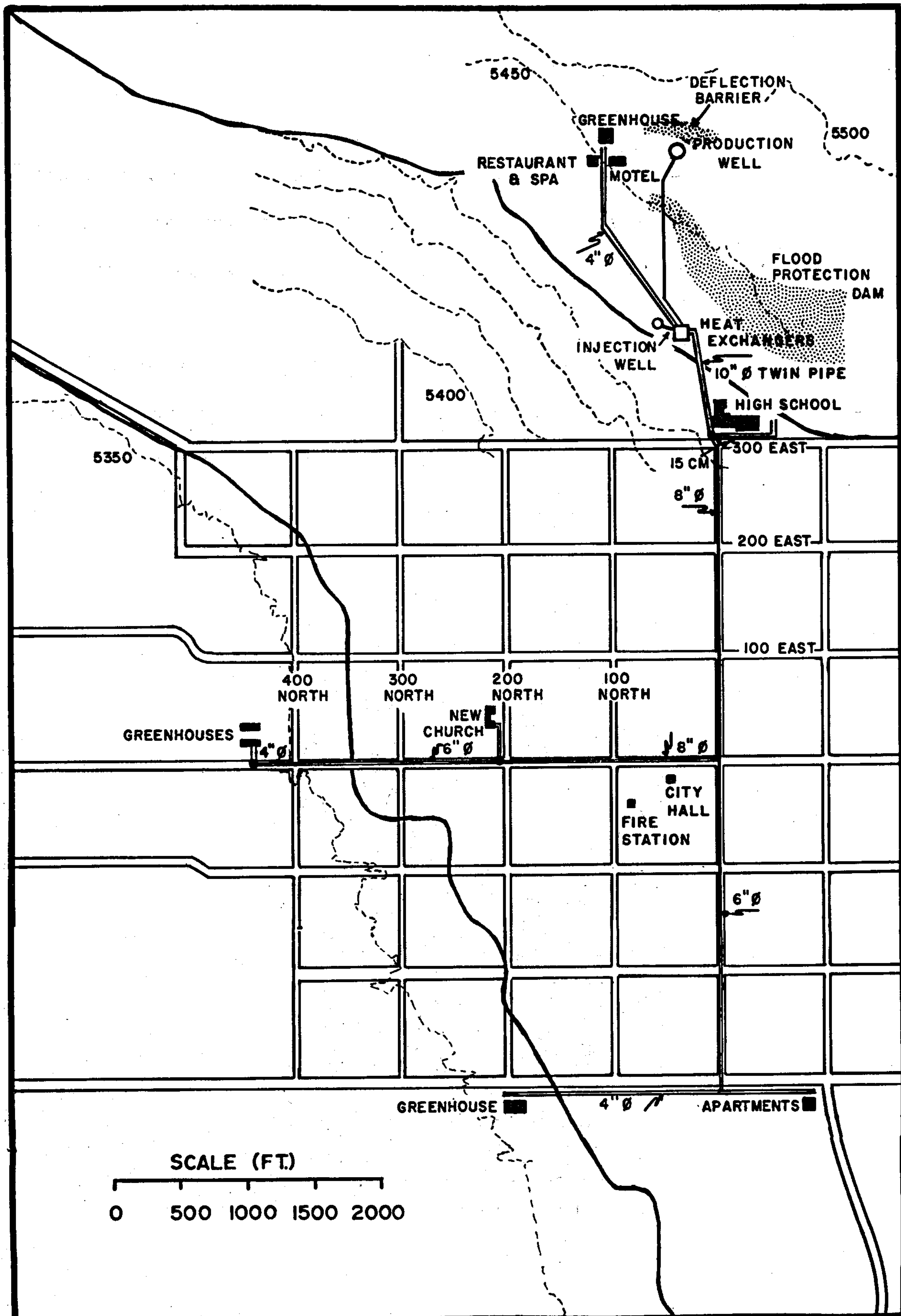

Figure 1. Overall plan of geothermal development.

GEOLOGICAL SETTING

The Monroe-Red Hill geothermal system is situated on the Sevier Fault near Monroe, Utah (see Figure 2). The proximity of the geothermal system to the town of Monroe presented an ideal situation for direct heat application if the resource base could be proven sufficient.

Geological and geophysical exploration of the geothermal system (Miller, 1976); Mase, 1978; Kilty, 1978; Chapman, et al., 1978) provided the following information: (1) the hot springs and geothermal system are structurally controlled by the Sevier Fault which separates upthrown Tertiary Volcanics to

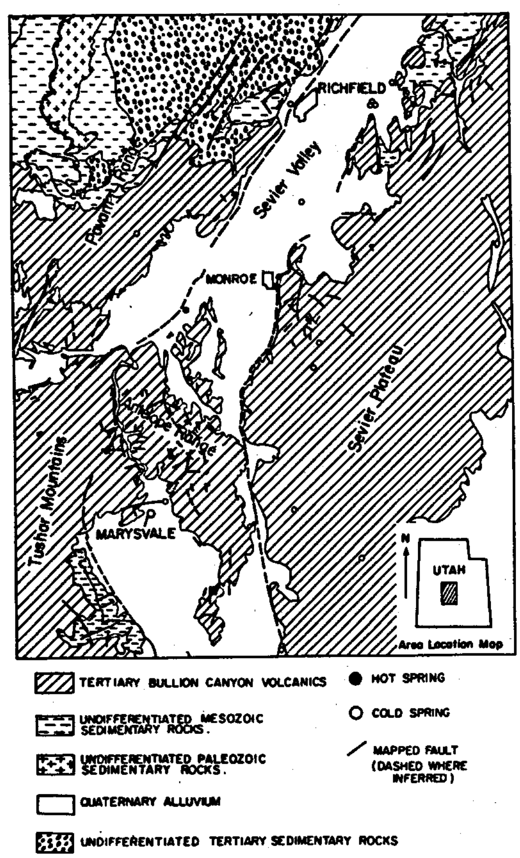

Figure 2. Location and General Geology of the Monroe-Red Hill Geothermal System

the east from Quaternary alluvium to the west; (2) the system is effectively mapped by dipole-dipole resistivity with low resistivities of 3 ohmmeters coinciding with discharge areas; (3) temperature-depth profiles show a pattern consistent with a model of hot water discharge essentially confined to the Sevier Fault zone which dips at an angle of about 67° to the west; and (4) the total conductive and convective heat loss for the system is 8 megawatts.

In order to further define the structural controls of the anomaly, two 6-3/4 inch diameter test holes, designated MC1 and MC2, were drilled to 360 feet and 824 feet, respectively. The well lithologies indicated in each

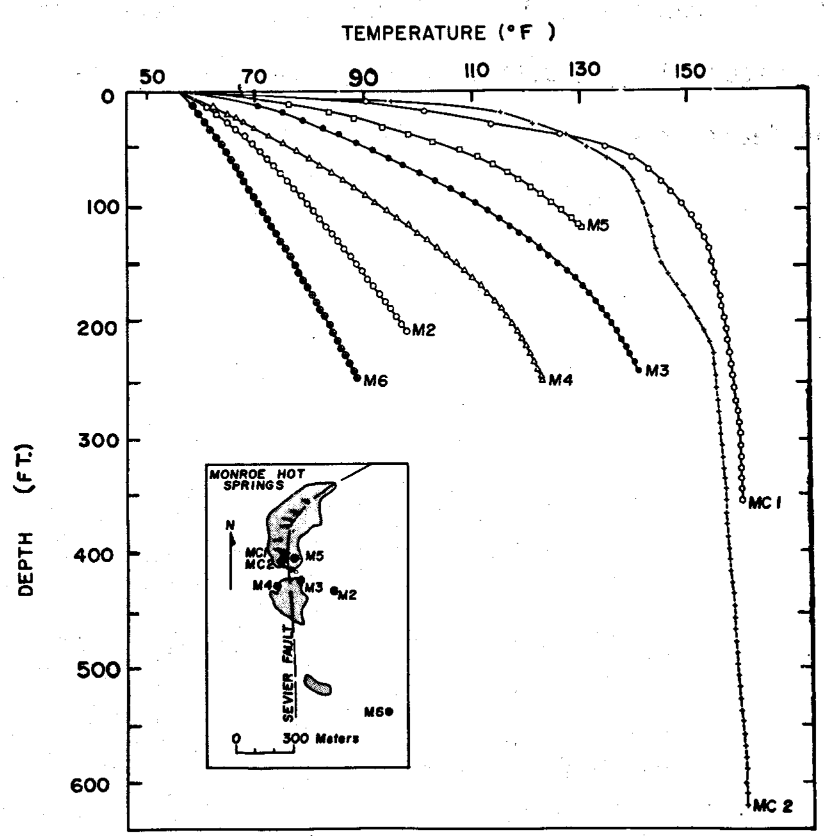

Figure 3. Temperature Profiles in Thermal Gradient and Test Holes

case a sinter deposit in the shallow subsurface, altered Quaternary alluvium consisting primarily of quartz latite fragments derived from the volcanic range to the east, and more consolidated volcanic bedrock at the base. The alluvium bedrock interface in each case was delineated by a change in the drilling rate, and the caliper, natural gamma, and lithology logs.

A dip of 67° ± 3° from horizontal for the Sevier Fault zone was computed on the basis of the intersections with more consolidated volcanics, well geometries, and an assumed fault trend of north 10° west. This dip is shallower than that deduced from the geophysical modeling and may indicate step faulting. Temperatures observed in MC1 and MC2 and the thermal gradient holes M1 to M4 shown in Figure 3, indicate a strong convective system rigorously confined along the fault zone.

WELL DESIGN

Strong artesian flows from fractures in the footwall of the fault at 750 feet led to the conclusion that the sinter deposits at the surface were capping a potentially productive resource driven by a strong hydraulic gradient. Penetration of fractures, thereby inducing production from depth was the principal goal of the production test drilling. Flow rates up to 600 gpm would be required to service the planned district heating scheme and therefore, a large diameter surface casing would be necessary to accommodate the appropriate pump should the natural productivity of the well prove to be inadequate. The well was designed and located on the basis of the geometry inferred from the test hole drilling to intersect the volcanic bedrock at 900-1000 feet. Alluvium was anticipated above this point. Major production was expected from fractures in the bedrock. It was felt that production from the 1000 feet plus level offered the advantages of good artesian flows due to increased driving potential with depth, the possibility of higher temperatures which would be of considerable benefit in view of retrofit requirements for existing building heating systems and minimum influence on surface hydrologic conditions. The final well design is shown in Figure 4.

A number of factors contributed to the well being completed in a different manner than was originally specified. After drilling the rat hole and cementing the conductor casing, drilling of the first pass (9-7/8" hole) proceeded as planned until a hard formation was intersected at 687 feet. Hard drilling persisted to 1313 feet although a number of clay stringers were intersected. A significant increase in the fraction of volcanic rock in the returned chips was noted from about 1050 feet.

Since drilling between 687 feet and 1313 feet had been difficult and in view of the high cost of 14-3/4" and 20" button reamers, it was decided to set

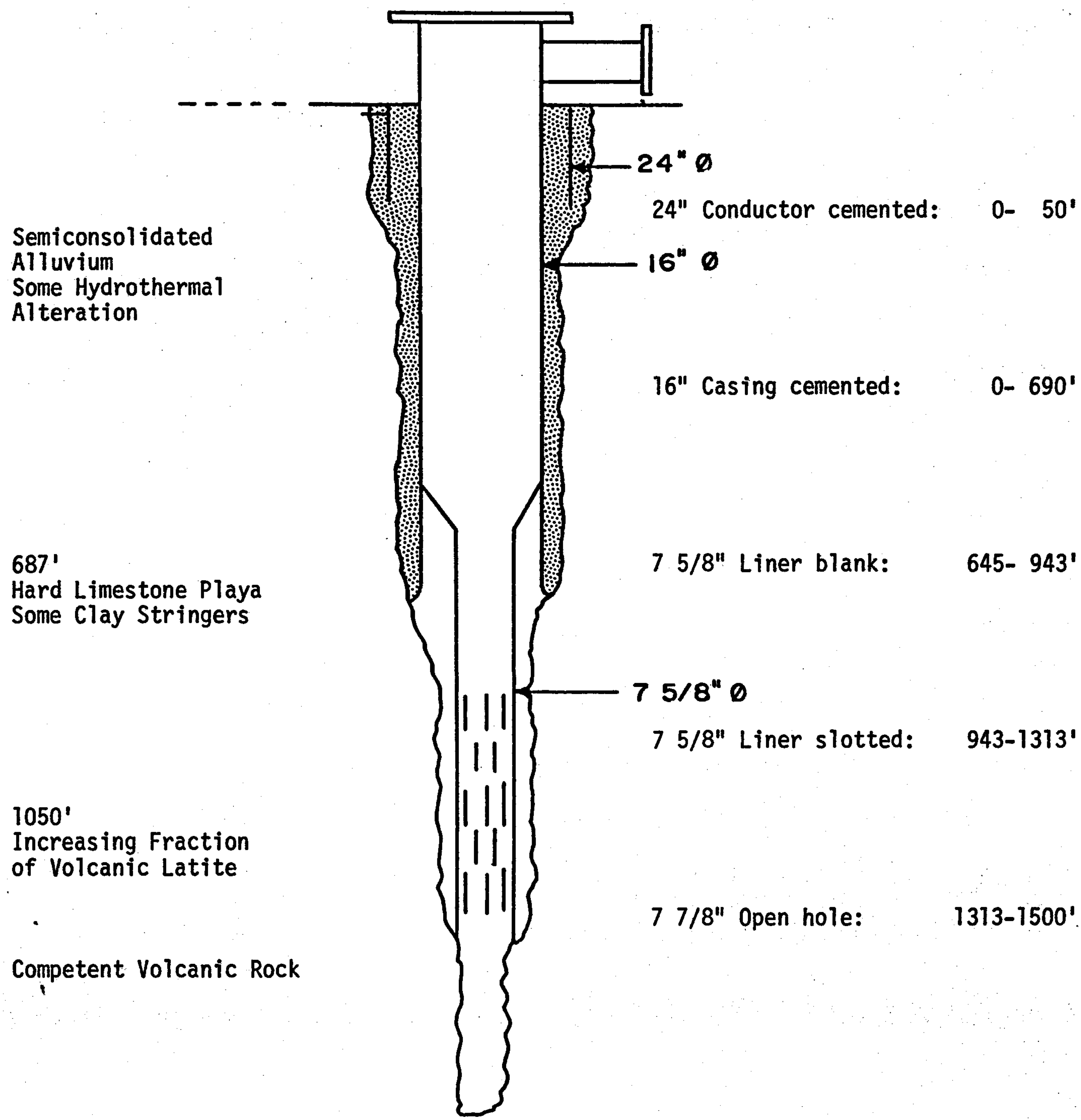

Figure 4. Production Test Well MC3.

the 16-inch casing at 700 feet rather than 1000 feet as originally planned.

The well was cleaned (fresh water circulated for approximately seven hours) at 1313 feet and then logged. Temperature logs indicated the bottom hole was still warming. Artesian flow was steady at about 85 gpm with a shut-in wellhead pressure (WHP) of 23 psig. When shutting in the well just prior to logging (the well had been flowing for approximately 10 hours) it was noticed that the wellhead pressure recovered quite rapidly to approximately 18 psi and then more slowly (over 10 minutes) to full WHP of 23 psi. The artesian flow was disappointing considering there was greater than 600 feet of open hole below the casing.

Reverse pumping was tried in an effort to stimulate greater artesian production and identify high permeability zones. Enough cold water was available to pump approximately one wellbore volume (~ 10,000 gallons). A temperature survey conducted immediately after pumping ceased indicated that most of the cold water entered the formation just below the casing with the result that little information was obtained on possible deeper production zones.

In view of the disappointing artesian flow (compared with the flow obtained from fractures at 780 feet in MC2) and the fact that a number of clay zones had been identified while drilling the 687-1313 foot interval it was decided to drill on to 1500 feet in the hope of finding a good producing fracture in the volcanics. The bottom 187 feet was drilled with a 7-7/8 inch bit using water. Since the lithology between 687 feet and 1313 feet was not completely understood and in order to avoid sloughing and sedimentation in the well, 700 feet of 7-5/8 inch liner (350 feet slotted) was placed in the interval before initiating a well testing program. Artesian flow tests before and after the liner was run indicated little loss in deliverability.

WELL TESTS AND RESULTS

Temperature Logs

Temperature logs in the production well after completion (see Figure 5) indicated abrupt changes in temperature at 943 feet and 1300 feet suggesting an influx of water into the wellbore at the top and bottom of the slotted liner and a slight warming at the bottom of the well when flowing artesian at 160 gpm compared to the shut-in condition. The latter is attributed to the diversion of warmer water, which would normally flow up the fault zone, into the bottom of the well where the local pressure is reduced below the surrounding reservoir conditions.

Flow Tests

The relative locations and elevations of the wells and springs monitored in the vicinity of the Monroe Mound during well testing are shown in Figure 6. The sequence of tests performed on the production well (MC3) and reservoir are listed below.

1) Artesian flow test (100 gpm for 8.33 hours).
2) Sequence of multirate flow test (of from 0.50 to 0.67 hours duration) interspersed with well shut-in (0.75 hours duration).
3) Drawdown (330 gpm for 70.25 hours)/recovery test (56 hours).
4) Compressed air stimulation treatment.
5) Post-treatment drawdown test (370 gpm for 2 hours).
6) High flowrate pump (618 gpm for 30 hours)/recovery test (30 hours).

For the stimulation treatment compressed air was pumped into the well (from the surface) over a period of 2-3 minutes until wellhead pressure reached 65 psi (approximately 113 gallons of water displaced). The air was

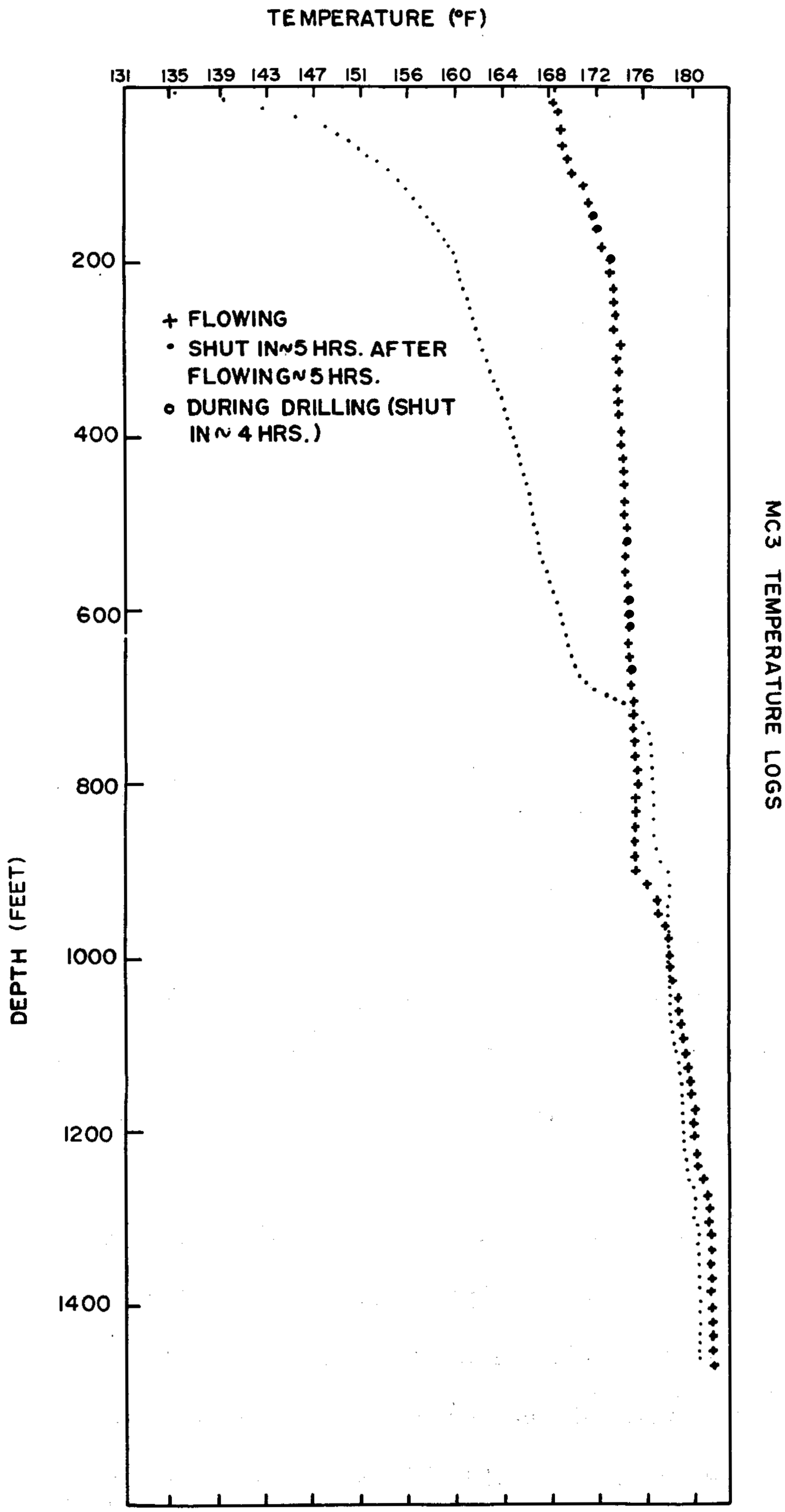

Figure 5. Temperature profiles in production well (MC3).

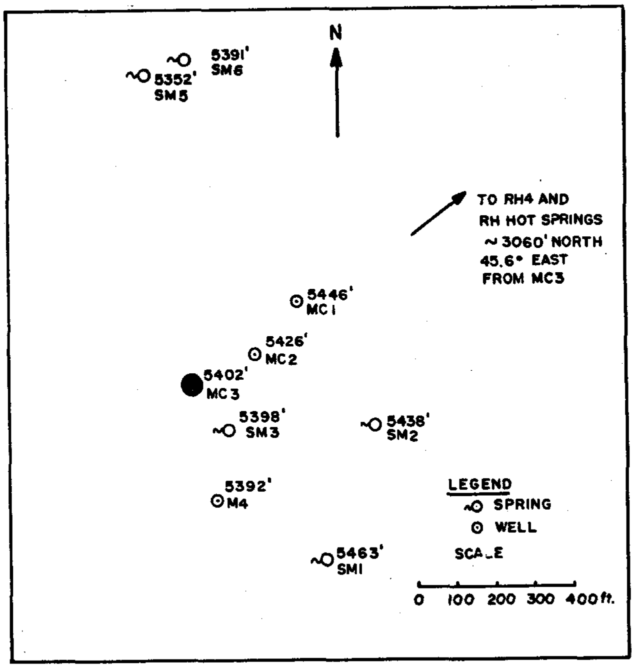

Figure 6. Location of springs and wells at the Monroe Mound
Production well Mc3 is emphasized.

bled quickly until the water level reached wellhead. After a pressure stabilization period a short drawdown test was performed to determine deliverability improvement. The treatment was repeated until no further improvement was evidenced.

The well test data provides clear indication that well completion was not optimum. A portion of the flow is from water in the colder shallow alluvium. Sealing the well from the colder water could require cementing and casing to 1400 ft. The final completion design would depend on results of reservoir testing in the isolated portion of the well below 1400 feet. The aim would be to detect and provide direct access to a supply fracture. However, the expense of drilling the well ($217,000 versus the budgeted $100,000 in the original proposal) and delays dictated no further completion work could be carried out.

Interpretation of Test Data

It is difficult to reconcile the characteristics of the production well with the responses shown in the monitor wells. In addition, the behavior of the production well appears to depend somewhat on the rate at which it is pumped. Obviously the hydraulic characteristics of the different formations present (i.e., alluvium, limestone playa and volcanics) and the effects of system recharge will complicate the interpretation of the pump test data. Nondarcy flow effects could also be a contributing factor.

The response of the production well is of paramount importance to the design of the district heating system for Monroe City. A first approximation of the well performance could be obtained by substituting the drawdown data obtained from the 618 gpm test along with estimates of reservoir storage from the monitor wells into the Jacob equation (Theis, 1935). Then with T = 300 ft^2/day, S = 0.0015 and r_w = 2.45 ft the general equation for drawdown versus time is:

$$s = 0.12\, Q_1 \left\{ \log_{10}(3125)t + \sum_{i=2}^{N} \frac{Q_i - Q_{i-1}}{Q_1} \log_{10}\left[3125\,(t - t_{i-1})\right] \right\}$$

where s = drawdown (ft), Q = flowrate (gpm), t = time (hours) and i denotes the interval over which any particular flowrate Q_i is maintained. The above equation resulted from a data fit to the drawdown in the production well during the high flowrate (618 gpm) pump test, Figure 7.

Although no recharge zones or boundaries were evident in the production well and monitor well drawdown curves, there were a number of breaks in slope in the recovery data, Figure 8. In addition, the production well drawdown data during the 70.25 hour 330 gpm pump test showed a definite break in slope after approximately 12 minutes, Figure 9. A recharge or high permeability zone at between 40 ft and 80 ft could influence the well in this way.

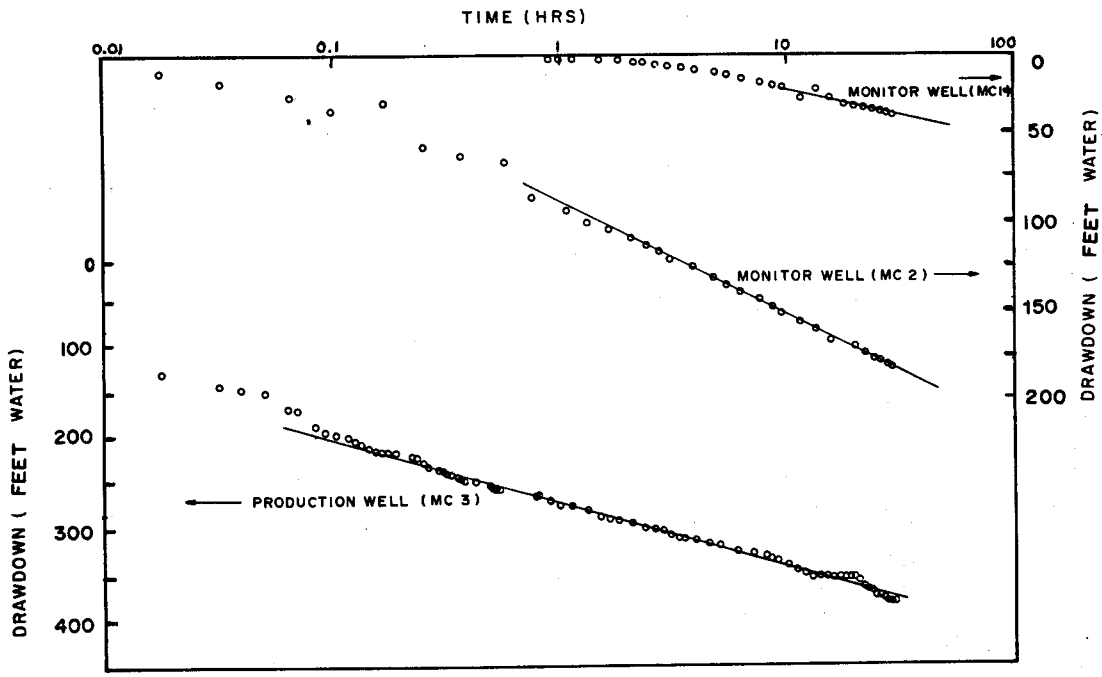

Figure 7. Drawdown during 30 hr 618 gpm pump test.

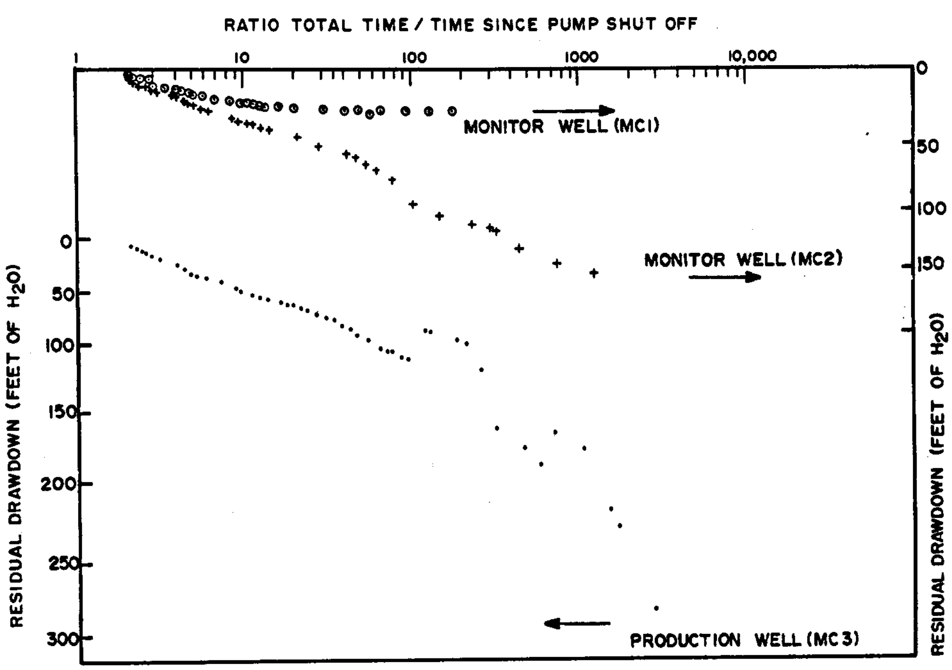

Figure 8. Recovery after 30 hour 618 gpm pump test

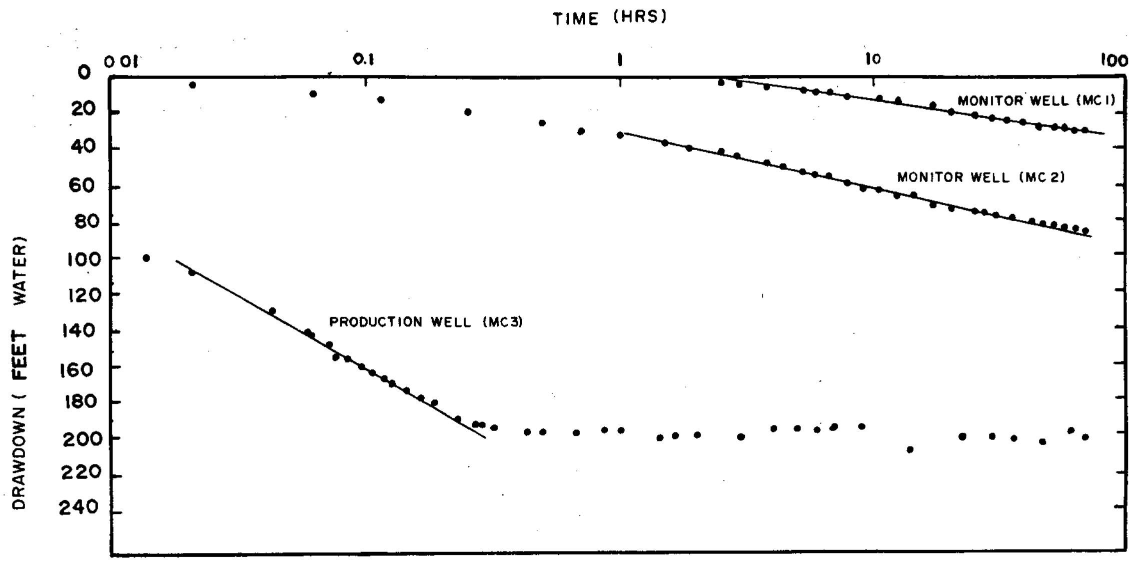

Figure 9. Drawdown for 70.25 hours 330 gpm pump test

It is possible that the effects of a small recharge would be masked when the production well flowrate is large (say 618 gpm) and more prevalent at the lower rate of 330 gpm. This would explain the apparent absence of the recharge effect in the 618 gpm (30 hour) test data.

Using a transmissivity of 300 ft/day, storage of 0.0015 and time for the pressure front to reach the discontinuity of 12 minutes (from the 70.25 hour, 330 gpm pump test) a distance to the boundary of 60 feet is obtained. This boundary could be represented by an image well located at approximately 120 feet from the production well.

Using the principle of superposition, the following equation can be written describing the drawdown in the production well.

$$s = \frac{Q_W}{4\pi T} W(u_w) + \frac{Q_R}{4\pi T} W(u_R)$$

s = drawdown, Q = flowrate, T = transmissivity and W (u_w) and W (u_R) refer to the well function for the production well and the recharging well. In this case:

$$u_w = \frac{r_w^2 S}{4Tt}$$

and

$$u_R = \frac{r_R^2 S}{4Tt}$$

where r_w = the effective well radius and r_R = the distance to the image well. A reasonable fit to the 2 hour, 380 gpm pump test data (see Figure 10) is

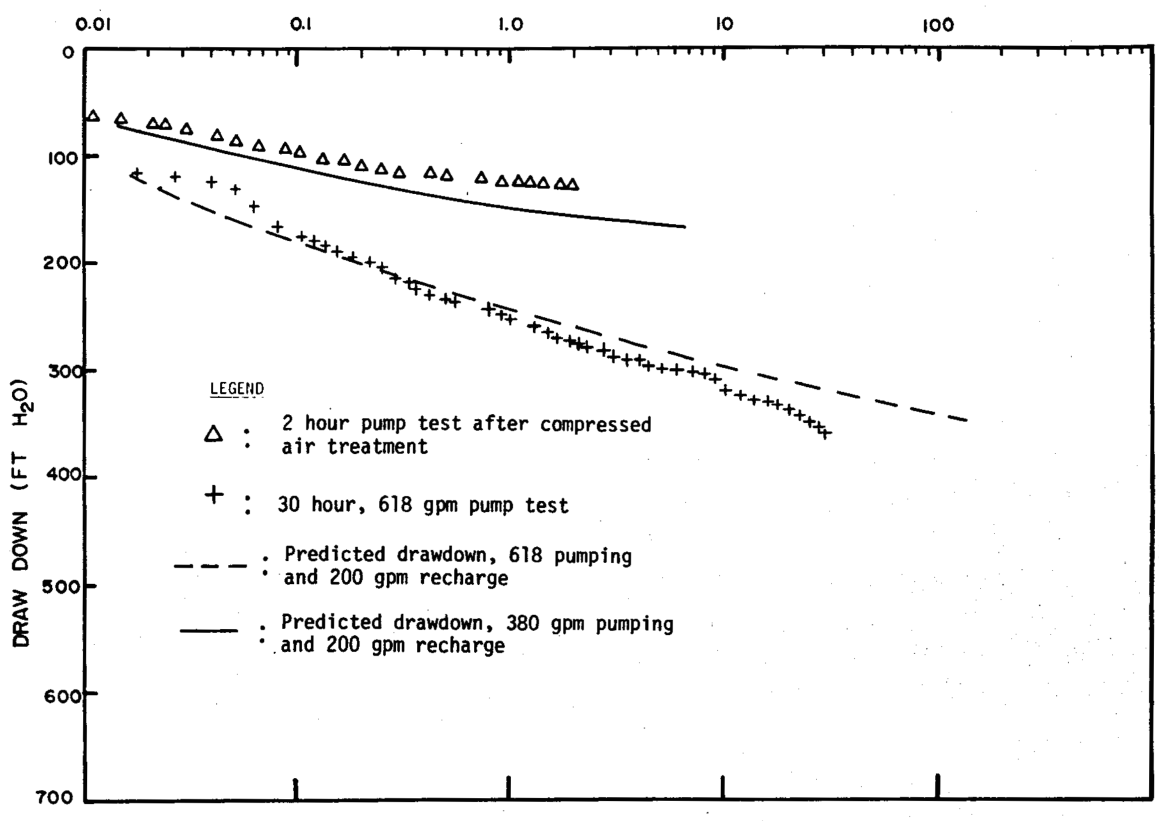

Figure 10. Comparison of drawdown data with predictions based on a recharging well analysis

obtained when $T = 300$ ft^2/day, $Q_R = 200$ gpm, $r_w = 2.45$ ft, $S = 0.0015$, and $r_R = 100$ ft. However, at the high pumping rate of 618 gpm, the inclusion of 200 gpm of recharge predicts absolute drawdowns and drawdown gradients less than those observed.

In view of the above it is felt that the application of simple Theis analysis should be used to predict the well response to pumping for the Monroe City district heating network.

WATER DISPOSAL

The Utah Water Pollution Committee requires the geothermal effluent be discharged into an "apparent" warm water zone which leaks northwest into the valley from between the Monroe and Red Hill hot springs. The approximate location of the disposal point and its relationship to the leakage zone, as evidenced by the tongue of resistivity low in the vicinity of RH3 is shown in Figure 11. The flow in this leakage zone has previously been estimated at between 700 and 1,400 gpm. An additional small quantity of water (180 gpm yearly average minus the approximately 100 gpm expected depletion of the

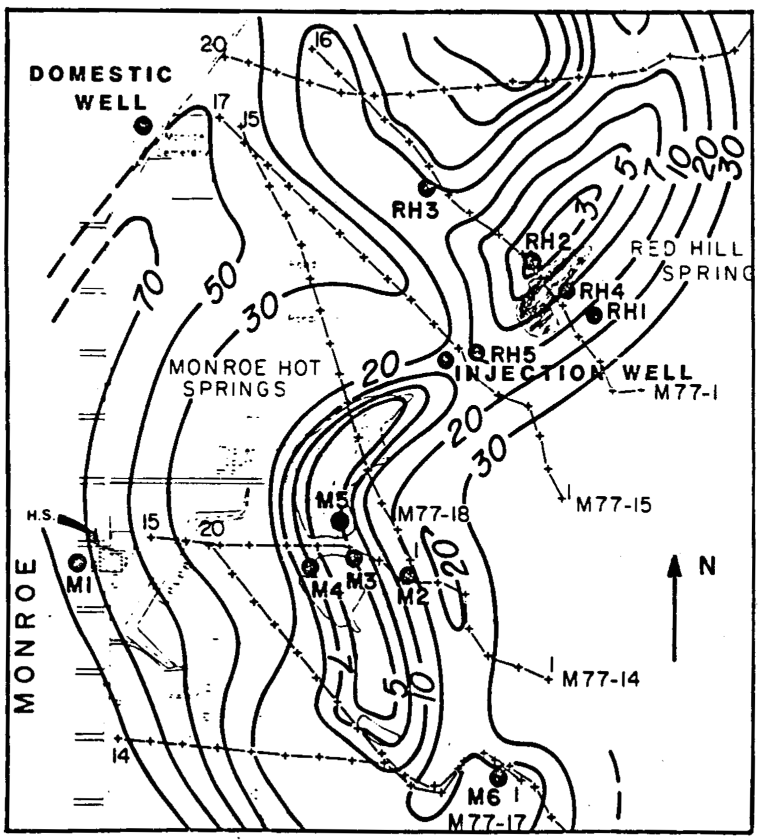

Figure 11. Location of Proposed Injection Well.

hotsprings) injected through a shallow well will be readily assimilated without disrupting the existing hydrology. A well 8 inches in diameter, 350 feet deep with the bottom 200 feet open to the formation could accept the peak flowrate of 600 gpm while producing an increase in water level in the immediate vicinity of the well of approximately 3 feet.

The injection well will not be drilled until program reevaluation has been completed although the Utah Water Pollution Committee has accepted the proposed injection scheme.

GEOCHEMISTRY

The chemical analysis of the production well water is:

Calcium	224 ppm
Magnesium	33
Sodium	558
Potassium	57
Silica	44
Sulphate	750
Chloride	750
Bicarbonate	435
TDS	~ 2700
pH	6.6

It will be necessary to maintain system pressures above the saturation pressure for carbon dioxide dissolved in the water in order to prevent calcite deposition in the primary (geothermal) system equipment. The concentration of CO_2 in the geothermal water was 0.03 percent by weight. Using Henri's law for CO_2 dissolved in water at 165°F, a CO_2 partial pressure of 6.1 psi is obtained.

CORROSION TESTING

A corrosion test to provide information on corrosion rates and relative deposition rates on different materials is in progress. The schematic of the test-system is shown in Figure 12. The materials being evaluated include:

- Admiralty brass
- Yellow brass
- Red brass
- Pure copper
- Monel 400
- Nickel 200
- 1018 low carbon steel
- 304 Stainless steel
- 316 Stainless steel
- Copper - 10% Ni
- Copper - 30% Ni
- Titanium - commercially pure, ASTM B265 Grade 2

All corrosion test coupons are 0.5 inch wide by 3 inches long by 1/16 inch thick except for the Admiralty brass which is 1/8 inch thick.

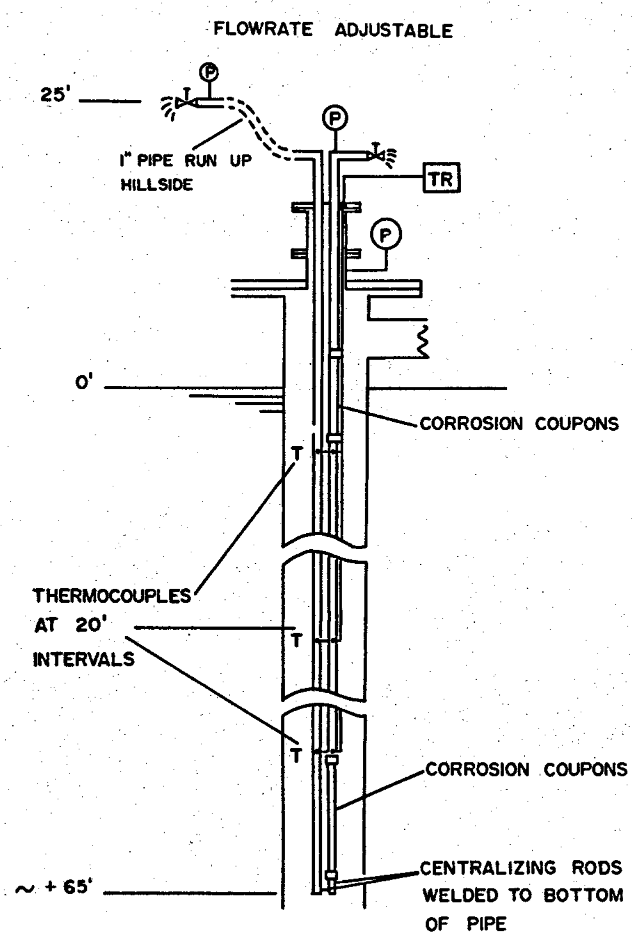

Figure 12. Schematic of Corrosion Test

PRELIMINARY DESIGN ANALYSES

Geothermal flowrate requirements, based on a preliminary design analysis of the proposed district heating system, and resulting well drawdown during a heating season are shown in Table I. The total required pump head at any given condition is equal to the drawdown plus approximately 40 feet to ensure the wellhead pressure is maintained above its saturation pressure for dissolved carbon dioxide. The heating season was arbitrarily split into equal segments on either side of the coldest day (when 600 gpm is required) in an effort to simulate a typical autumn to winter to spring heating cycle. The average flowrate required over the 7028 hour heating season is 224 gpm of 165°F water. This converts to an average yearly requirement of 180 gpm and compares favorably with the approximately 200 gpm measurable hot springs discharge of Monroe and Red-Hill.

TABLE I

GEOTHERMAL FLOWRATE REQUIMENTS FOR 74°C WATER

HEATING SEASON INTERVAL HOURS	CUMULATIVE TIME HOURS	AVERAGE AMBIENT TEMP. DURING INTERVAL (°F)	AV. FLOW FROM WELL GPM	DRAWDOWN FT	REQUIRED PUMP HEAD (FT)
594	594	60	100	5	45
634	1228	50	114	20	60
728	1955	40	169	64	104
794	2748	30	261	139	179
528	3276	20	375	220	260
187	3463	10	520	332	372
100	3564	0	600	389	429
187	3751	10	520	345	405
528	4279	20	375	245	305
794	5072	30	261	161	201
728	5800	40	169	90	130
634	6434	50	114	46	86
594	7028	60	100	32	72

System Outline

The Phase I development consists of the following major items.

Item	Location
Supply Well and Pump House	10 North 620 East
Heating Plant	50 North 420 East
Return Well	290 North 760 East
High School Retrofit	50 South 300 East
Primary Piping	Supply Well to Heating Plant to Return Well
Secondary Piping	Heating Plant to High School
	Center Street: 300 West to 300 East Main Street: Center Street to 400 North (See Figure 1).

Total Potential Heating Loads are estimated to be as follows:

High School		2400 MBH*
Monroe City		
73 Residences @ 60 MBH (±) . . .	4380	
Elementary School	1000	
Junior High School	1320	
L.D.S. Chapel	500	7200
TOTAL ESTIMATED LOAD		9600 MBH

*MBH = 1,000 BTU/hr

The South Sevier High School Load was estimated from tests performed on January 8, 1979, by Terra Tek as follows:

		Air Temperatures °F			Heating Water			
Condition	Date	Outside	Inside	ΔT	GPM	Supply °F	ΔT °F	MBH
Test by Terra Tek	1/8/79	13	75	62	625	170	7.20	2250
Required @ 65°F Inside Air Temp.	12/18/79	5	65	60	625	156	6.97	2177
For 0° Design Condition	12/18/79	0	65	65	625	156	7.68	2400

The peak high school load is then 2400 MBH and is provided by a hot water, coal fired boiler system. The boiler delivery temperature is maintained at a constant 180°F. The delivery temperature to the various zonal units in the building is determined by a temperature reset schedule based on outdoor ambient temperature.

The observations by Terra Tek on January 8, 1979, were made when the inside air temperature was 75°F. Emergency Building Temperature Restrictions were declared by President Carter to be effective as of July 16, 1979, to implement the national effort to conserve energy. The inside air temperature is to be no higher than 65°F during the heating season compared with 75°F previously.

Domestic water under the Emergency Building Temperature Restrictions is to be maintained at a temperature no higher than 105°F. It is expected that this reduction in temperature will result in the existing equipment in the high school being capable of servicing the load without major modification.

Realistic near term loads on the system would include:

High School	2400 MBH
30 Residences @ 60 MBH	1800
Total	4200 MBH

The Elementary School has a steam heating system and would be very expensive to retrofit. The Junior High School and LDS Chapel have not yet been constructed (expected within 5 years). Peak requirements for the City Hall and Fire Station are estimated to be approximately 100 MBH each. These loads are not significantly greater than an ordinary residence and are therefore assumed to be part of the residential load estimate.

System Design Features

Figure 13 shows the basic layout of the proposed system. The design calls for a total peak load of 9600 MBH to be serviced by extracting 32°F from a geothermal flow of 600 gpm. Heated fresh water will be circulated from the heat exchangers to the South Sevier High School where up to 8°F will be extracted. The water will be subsequently circulated through the town in a closed loop, double pipe mains system. This configuration ensures efficient use of the resource and avoids the necessity of extensive retrofit in the high school.

Primary Water System/Deep Well Pumps: Geothermal flowrate requirements and well drawdown are shown in Table I. The geothermal flow requirements were determined on the basis of temperature data for Richfield, Utah, obtained from the State Climatologist. These estimates are requirements for an average heating season and could be exceeded in any given season.

Two options for the deep well pump were considered; (1) a single variable speed shaft pump and (2) two or three identical submersible pumps each capable of producing the appropriate fraction of the total output. Pump speed, head and power requirements, calculated from similarity laws and assuming constant efficiency operation over the full range of speeds (very optimistic) for a single pump set to approximately 600 feet is shown in Table II below.

TABLE II

PUMPING CHARACTERISTICS FOR A VARIABLE SPEED PUMP

FLOWRATE GPM	PUMP SPEED PERCENT OF MAX.	PUMP HEAD (FT)	POWER HP
600	100	550	126
520	87	416	83
480	80	352	64
<480	<80	>352	~64

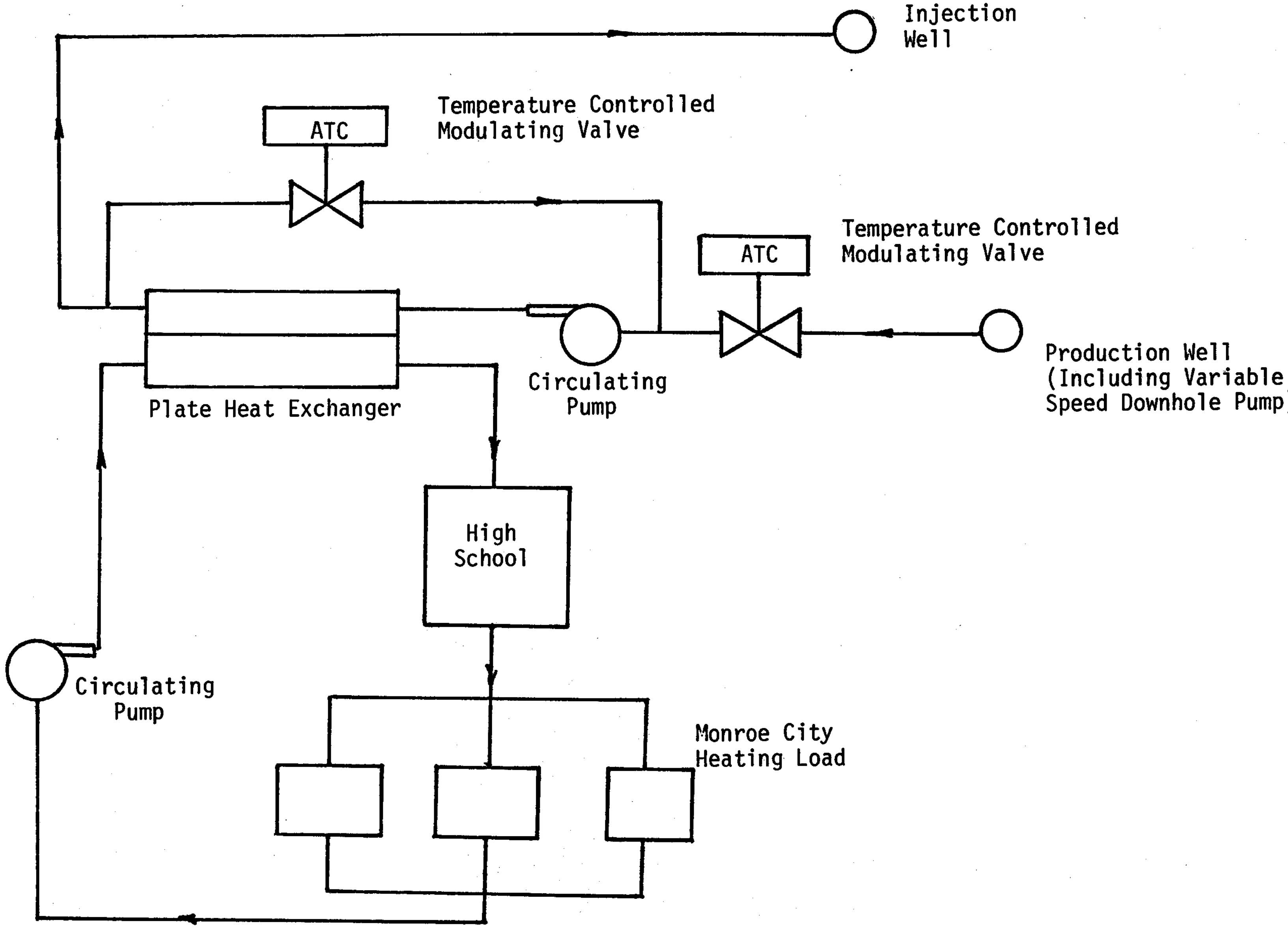

Figure 13. Proposed System Schematic

For flowrates less than 480 gpm the pump speed is held constant and the flow is controlled using a valve. This is necessary since the actual pump delivery head at reduced speed decreases at a greater rate than the required head to lift the water from the well. The total pumping power consumed during the heating season for the variable speed case is approximately 3.5×10^5 kwh.

The delivery and power requirements are shown in Table III below for three identical submersible pumps in the well. Each is capable of delivering 200 gpm at a maximum head of 500 feet.

TABLE III

PUMPING CHARACTERISTICS FOR MULTIPUMP OPERATION

FLOW FROM WELL	NO. PUMPS OPERATING	EACH PUMP GPM	HEAD FT.	EACH PUMP HP	TOTAL HP	FREQUENCY HZ
600	3	200	502	42	126	60
439	2	220	477	42	84	60
311	2	156	363	45	90	50
210	1	210	268	47	47	50
127	1	127	427	44	44	50
100	1	100	460	42	42	50

The pumping energy consumed during the heating season for this case is approximately 2.1×10^5 kwh.

Final selection of the well pumping system has not been made as yet since some optimization of the variable speed case may be possible. Further analysis will be carried out when particular pump characteristics for the two cases become available (currently on order from suppliers). Preliminary studies, however, did not indicate a significant cost difference between the two options and therefore the multipump option was chosen for the purpose of this analysis on the basis of reduced power consumption and backup capacity.

Primary Water System/Primary Pumping: The Rovanco piping system with a Bonstrand 2000 carrier pipe was chosen for the delivery line from the well to the heating plant. This system offers the necessary mechanical strength characteristics at the delivery temperature of 164°F and pressures exceeding 100 psi and can be cleaned with an acid flush if calcite deposition occurs.

Other nonreinforced plastic pipe systems were considered, however, they were discarded on the basis of lack of adequate data on long term stability (>10 years) at high operating temperatures and pressures. Asbestos cement was discarded due to the inability of using acids for cleaning purposes.

Primary Water System/Heating Plant: Main equipment items for the heating plant include:

ITEM	NO.	DESCRIPTION
Heat Exchanger	1	Plate Type SS316
Main Circulation Pump	2	Centrifugal, 600 gpm, 30 ft (1 standby)
Air Separator	1	
Expansion Tank	2	
Primary Control Valves	2	Controlled by Secondary Delivery Temperatures
Primary Circulation Pump	1	Centrifugal, 600 gpm, 20 ft
Building	1	900 sq ft - will accommodate expansion

Primary Water System/Heat Exchangers: A circulating pump in the primary piping provides a constant flow of 600 gpm to the Plate Heat Exchanger with a varying flow from the well. The degree of mixing or recirculation is determined by the secondary delivery temperature requirements. A constant flow of 600 gpm is maintained in the secondary system. This constant flowrate is necessary since the high school is in series with the City system and requires a constant circulation rate of 600 gpm.

At peak load, water is pumped from the plate heat exchangers at 155°F (i.e., temperature difference between primary and secondary = 8°F) to the high school where 8°F is extracted through the high school space heating system. The water is then piped through the town where an additional 24°F is extracted, returning to the heat exchangers at 124°F.

It should be noted that the existing high school heating system is designed to accommodate high circulation rates through the mains with the individual zonal heating equipment extracting only very small ΔT's. Conversion of the system to accommodate significantly higher ΔT's would involve a very expensive retrofit. As a result, the high school essentially controls the pumping rate from the well. For example, if the high school was the only load on the system, then 600 gpm peak would still be needed in order to service the school with 156°F water. This, of course, is an inefficient use of the resource. However, it is necessary if the high school is to be serviced with geothermal heat at peak load conditions while avoiding extensive retrofit of existing systems in the school.

During periods of partial load the secondary supply temperature is altered down from peak temperature of 156°F according to a reset schedule which is controlled by the ambient air temperature. This delivery temperature control is necessary in order to minimize the pumping from the well. Flowrates and system temperatures are shown in Table IV for various partial load conditions.

An alternative to recirculation and mixing on the primary side would be to control the flowrate in the heat exchanger. The APV "Heat Transfer Handbook" for Design and Application of Paraflow Plate Heat Exchangers" discusses the effects of flow velocity on the fouling resistance of heat exchangers. A plot of fouling resistance versus time for different velocities shows that

TABLE IV. ESTIMATED TEMPERATURES AND FLOWS

SPACE HEATING OF HIGH SCHOOL, CENTER STREET AND MAIN STREET												
	PRIMARY WATER						SECONDARY WATER					
	TEMPERATURES @ HEAT-X				FLOWS IN TO HEAT-X		MBH			TEMPERATURES		
OUTSIDE AIR TEMP. °F	IN PER RESET SCHED. °F	IN PER MIN. GPM FROM WELL °F	ΔT °F	OUT °F	FROM WELL GPM	RETURN FROM HEAT-X GPM	HIGH SCHOOL SPACE HTG	MONROE SPACE HTG	TOTAL	FROM HT-X TO H.S.	FROM H.S. TO MONROE	FROM MONROE TO HT-X
5	164	---	32.00	132.00	600	0	2400	7200	9600	156.00	148.00	124.00
15	154	---	26.67	127.33	439	161	2000	6000	8000	146.00	139.33	119.33
25	144	---	21.33	122.67	311	289	1600	4800	6400	136.00	130.67	114.67
35	134	---	16.00	118.00	210	390	1200	3600	4800	126.00	122.00	110.00
45	124	---	10.67	113.33	127	473	800	2400	3200	116.00	113.33	105.33
55	114	137.35	5.33	132.02	100	500	400	1200	1600	129.35	128.02	124.02
65	104	---	---	---	---	---	0	0	0			

* SECONDARY OUT °F = PRIMARY IN °F -8°F

increased fouling occurs as velocity decreases. In view of the 6 to 1 ratio between peak flow and minimum flow from the well and the expected fouling tendency of the water, recirculation to maintain optimum flow conditions in the heat exchanger is preferred to throttling.

The difference between the two modes of operation can be examined using the following equation for convective heat transfer:

$$q = hA\Delta T_m$$

where q is heat flux, h is the heat transfer coefficient, A is the heat exchanger area and ΔT_m is the log mean temperature difference. From the Colburn equation, for constant fluid properties, the heat transfer coefficient is related to the flowrate by

$$h \propto Re^{0.8}$$

where Re is the Reynolds number (VD/μ). Substituting for constant heat exchange area and constant fluid properties gives

$$q \propto V^{0.8}\Delta T_m$$

Since the velocity (V) is proportional to the volume flowrate (Q),

$$q \propto Q^{0.8}\Delta T_m$$

<u>Constant Flow Case</u>

For the case of constant flow in the heat exchanger:

$$q \propto \Delta T_m$$

and since the flow in each side of the heat exchanger is the same (600 gpm) then:

$$\Delta T_m = T_{\text{primary in}} - T_{\text{secondary out}}$$

The proportion of the total flow (x) supplied from the well at any given partial load condition can be found from a heat balance as follows:

$$600(T_{pi} - T_{po}) = (600 - x)T_{si} + xT_d$$

where the subscripts pi refer to primary in; po — primary out; si — secondary in, and d — delivery (164°F).

<u>Variable Flow Case</u>

For the variable flow case both flowrate (Q) and temperature difference (ΔT_m) vary. For partial load conditions

$$\frac{q_1}{q_2} = \left(\frac{Q_1}{Q_2}\right)^{0\cdot 8} \frac{\Delta Tm_1}{\Delta Tm_2}$$

The flowrate Q is expressed by:

$$q = \frac{Q}{p} C_p \Delta T$$

where ΔT is the temperature/drop increase in the fluid. On substituting

$$\frac{q_1}{q_2} = \left(\frac{q_1/\Delta T_1}{q_2/\Delta T_2}\right)^{0\cdot 8} \frac{\Delta Tm_1}{\Delta Tm_2}$$

from which ΔT_2 can be found for any given value of q_2 (partial load) and hence the previous equation can be solved for the flowrate Q_2.

Table V below compares the geothermal flowrate requirement for the two cases of constant and variable flow in the heat exchanger over a range of load requirements.

TABLE V

HEAT EXCHANGER FLOWRATE REQUIREMENTS

LOAD MBH	SECONDARY DELIVERY TEMP.	REQUIRED FLOWRATE (GPM) CONSTANT	VARIABLE
9600	156	600	600
8000	146	421	393
6400	136	291	271
4800	126	192	182
3200	116	114	110

In practice it is unlikely, in the variable flow case, that flowrates of 182 and 110 gpm could be achieved for loads of 4800 and 3200 MBH since this involves approach temperatures of less than 1°F at the cool end of the heat exchanger.

In any event, the difference between the two cases is small and it is likely that over a period of time the constant flow option would exhibit superior performance due to reduced fouling tendency.

Secondary Piping

The secondary piping system has been sized to accommodate three times the existing pumping rates. This is to allow for future expansion of the system. Expansion of the system beyond the potential 9600 MBH currently planned would almost certainly require drilling of additional production wells. Pipe diameters could be reduced by approximately 40 percent if the system was to be resized for the current capacity only.

Both the outgoing and return mains are insulated. Heat loss analyses predicted temperature drops of approximately 11°F for the noninsulated case, 8°F for the outgoing only insulated case and 2°F for both pipes insulated. Temperature drops of 8°F and 11°F are unacceptable in view of the marginal nature of the resource (both temperature and capacity).

Cost estimates were developed for two options; (1) Temptite (an insulated AC carrier pipe with liner and AC jacket) and (2) Rovanco (an insulated FRP carrier and PVC jacket). The Temptite system is significantly less expensive than FRP, however, it is susceptible to damage during installation and thermal shock during operation. Both suppliers quote satisfactory long term performance histories for systems installed and operated within the manufacturer's specifications. In view of the above it is recommended that Temptite pipe be used in the secondary mains network.

Other "insulated" in place piping systems were considered. However, since reliability is a major factor in the selection it was felt that the potential maintenance problems associated with these systems did not justify the short term cost benefits.

Disposal

A disposal line will be run from the heat exchangers to an injection well located between the Monroe and Red Hill Mounds. The line will comprise a buried uninsulated fiberglass reinforced plastic pipe (Bonstrand 2000).

Connections to Individual Buildings

A general layout of a connection from the main to a small building or residence is shown in Figure 14. Connections to individual buildings are arranged to provide a constant water flow through building laterals. Energy charges to individual customers will be based upon the operating time for cabinet heater fans, along with the constant flow through the laterals.

Connections and conversion costs for a household, assuming a forced air system is already installed, are given below:

ITEM	COST
Underground Pipe (From Main):	
Pipe (1" schedule, 40, steel, uninsulated) 160@ 0.75/ft	$ 120
Trenching 28 cu ft @ $2.50	70
Compacted Backfill 28 cu ft @ $3.50	98
Bituminous Paving Patching 40 sq ft @ $2.00	80
Fittings (steel):	
Elbows 3 @ $ 0.51	2
Tees 1 @ $ 1.00	1
Yoke 1 @ $20.00	20
Connection to Main 2 @ $20.00	40
Ball Valves 2 @ $14.00	28
Valve Box 1 @ $6.00	6
Interior Work:	
Unit Heater (50 MBH)	$ 488
Pipe (steel insulated 30 ft @ $3.00/ft)	120
Fittings:	
1" Elbows 12 @ $0.51	7
1" Unions 3 @ $8.00	24
Ball Valves 1" 3 @ $14.00	42
Strainers 1" 1 @ $15.00	15
Meter	50
Electrical	75
TOTAL	$1,286

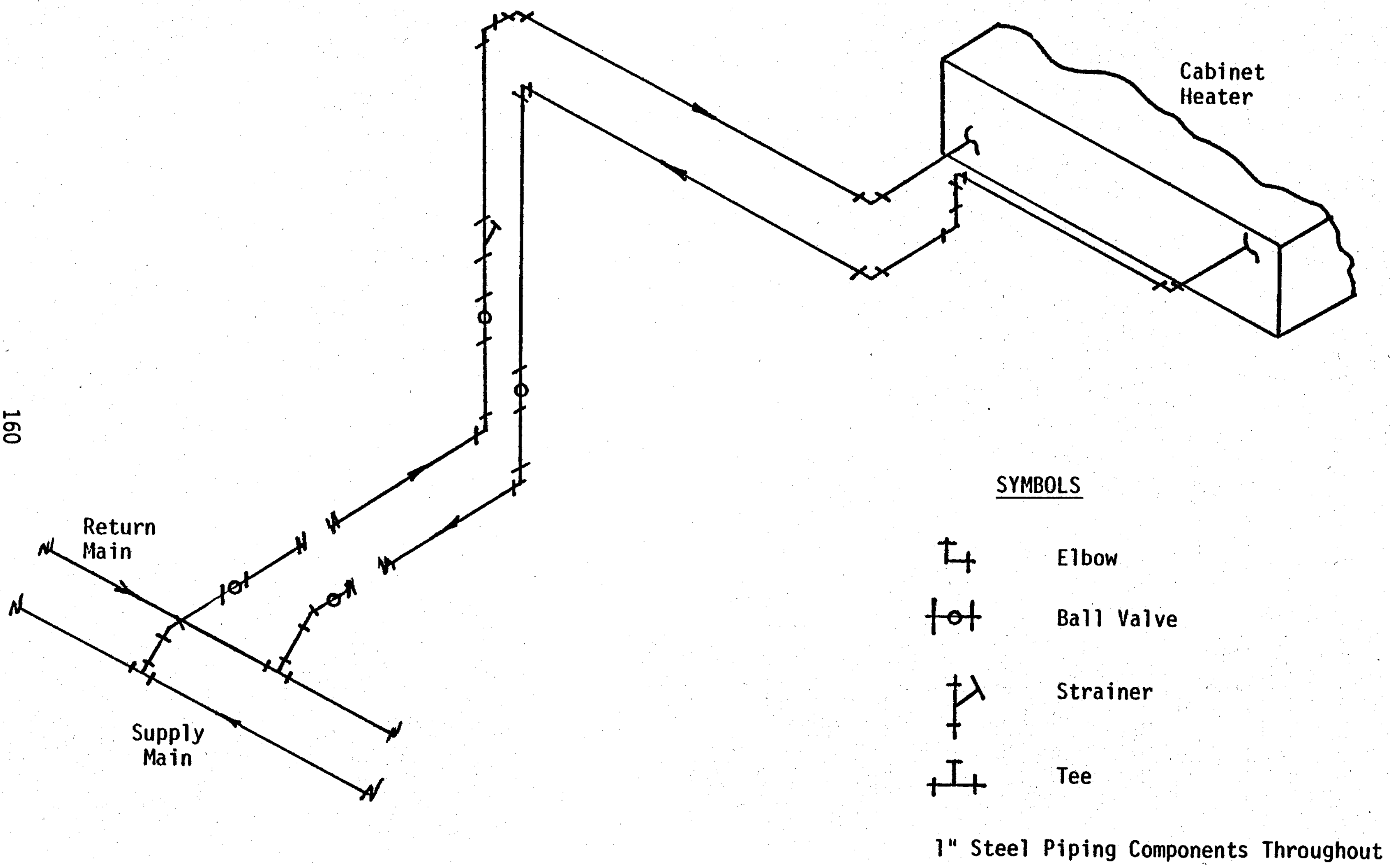

Figure 14. Typical Building Connection

COST ANALYSIS

The capitalization and operating costs for the Phase I district heating system as previously described in the text are summarized in tabular form.

Capitalization Costs

ITEM	COST
TOTAL INSTALLED HARDWARE COST	$1,188,748*
PRODUCTION WELL	
Drilling (completed)	217,000
Testing Supplies (completed)	20,000
INJECTION WELL	
Drilling	80,000
Testing Supplies	15,000
ENGINEERING	
Labor and Travel	394,000
SCHEME IV TOTAL	$1,914,748
Spending as of 1/1/80 (DOE Share)	389,500
Cost to Completion	$1,525,248

*Based on Temptite (Johns-Manville supplied insulated A/C pipe) in secondary.

Expected Operating Costs

ITEM	COST
WELL PUMPING (Based on number of pumps operating and interval of operation)	$ 8,500*
CIRCULATION PUMPS	500*
LABOR	
1 Man Maintenance @ $15,000 (includes benefits)	15,000
1/2 Person Administration (@ $12,000)	6,000
Replacement Parts, etc.	6,000
TOTAL YEARLY COST	$36,000
Add 7% of Revenue for Royalty	2,320
TOTAL OF YEARLY COST TO UTILITY	~ $38,500

*Based on 4¢/kwh.

Mr. John Austin (CH2M Hill Company, 1980) noted that the expected annual operating costs are only 2½ percent of the capitalization costs. True operating costs are more likely to be twice this. Moreover, reducing the extent of the district testing scheme does not greatly reduce the operating costs. For example, the analysis indicates that the difference in pumping costs between servicing the complete development and servicing the high school only is approximately $800 per year.

Expected Revenues

For purposes of comparison the expected revenues are based on the assumption that each user would pay the same amount for geothermal heat, as he currently pays for coal (coal cost $42/ton, 12,500 BTU/lb, 60 percent combustion efficiency). Average yearly load is assumed to be 28 percent of peak demand.

SYSTEM	AVERAGE LOAD MBH	REVENUE
High School + 73 Residences + Elem. School + Jr. High School + LDS Chapel	2688	$59,000
High School + 73 Residences + Elem. School	2178	$47,700
High School + 73 Residences	1900	$41,600
High School + 30 Residences	1176	$25,800
High School	680	$14,700

The expected revenues when compared to costs indicate the district heating system would require a subsidy for operation. The system obviously does not have the potential to generate capital for expansion to the full district heating system as proposed in Phase 2 and 3.

SUMMARY

The following conclusions are based on the resource development, test program, and system design work reported.

(1) The Monroe/Red-Hill thermal anomaly as defined by the resistivity and heat flow surveys is a moderate temperature system rigorously confined to the Sevier Fault Zone. An apparent structural discontinuity in the Fault provides the plumbing for forced convective discharge of deep circulating water to the surface. The lack of Pleistocene and Quaternary volcanism in the area suggests that the system is in a thermally stable condition supported by the high regional heat flow common to the Basin and Range Province.

(2) The resource temperature is marginal for district heating purposes. Recent geothermometry interpretations provided in "Assessment of Geothermal Resources of the United States - 1978", Geological Survey Circular 790, published in 1979 suggests that the Monroe/Red-Hill Hot Springs maximum source temperature is between 174°F and 237°F. Temperatures of 180°F have been observed at the bottom of the existing well; substantially higher resource temperature is unlikely. However, it is considered possible to achieve surface temperatures on the order of 180°F at higher flow rates by optimization of well completion.

(3) System design analyses indicate that due to the low temperature of the recovered resource, the high pumping costs, and the large areal/low population density to be served, the district heating system, based on the present well capability, is not economically viable.

(4) The program is currently being reassessed by Monroe City and the Department of Energy for possible redirection.

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BOISE GEOTHERMAL DISTRICT HEATING SYSTEM

Phillip J. Hanson, Director, Boise Geothermal
Nathan H. Little, Project Manager, CH2M HILL

ABSTRACT

Two 10-megawatt geothermal district heating systems are being developed by the City of Boise and the Boise Warm Springs Water District (BWSWD) for Boise, Idaho. These systems will provide 170°F geothermal water for space heating in downtown Boise and eastern Boise, respectively. This paper provides a general description of the project and summarizes its current status.

PROJECT DESCRIPTION

Resource

The oldest rock unit in the project area is the Idaho Batholith. Typically upon faulting, the rock is broken into numerous subparallel shear zones steeply dipping. One such very prominent zone has been named the Foothills Fault, which trends parallel to the Boise front. It is this fault that provides the conduit for the upward migration of much of the goethermal water that occurs along the Boise front.

The next most important formation in the project area is the Glenns Ferry formation. This unit consists of thickly interbedded clay, sand, silt, and thin layers of fine gravel with occasional discontinuous basalt flows. The project production zone will probably be permeable lenses within the Glenns Ferry formation near the contact with the granitic rock adjacent to the Foothills Fault. Production will probably take place at relatively shallow depths (500 through 2,500 feet). Geothermal wells presently existing in the project area range in temperature between 140°F to 175°F. The geothermal water in the Boise area is very high quality. However, the water does have high concentrations of fluoride (15 through 25 parts per million), which will be accounted for in project planning.

Two wells presently serve the existing BWSWD system and provide a peak flow rate of approximately 1,700 gallons per minute (gpm). A third well developed under the current project is expected to increase that flow by a minimum of several hundred gpm. Preliminary planning for the City system has been for two 1,000-gpm wells. Ultimate flow rates will depend upon further geology work, and testing to be done during the drilling of the first wells.

Design

The proposed Boise City and BWSWD systems will utilize the local geothermal resource, as described above. Production wells for the City system will be located approximately 1-1/2 miles from the primary load located in downtown Boise. The pipeline will be sized for 4,000 gpm to allow for future growth, although initial production capacity is expected to be approximately 2,000 gpm. The BWSWD pipeline will be sized for 3,000-gpm flow maximum.

Production well pumps will deliver water to the transmission pipelines through pressure control valves. The transmission pipeline pressure, and thus the system load, will be sensed and automatically maintained by adjusting pressure control valves. System flows, temperatures, and pressures will be monitored and recorded. Customer service connections for the City system will be made between the transmission and collection pipelines, using a primary-secondary crossover hydronic circuit. This arrangement will tend to hydraulically isolate customer system characteristics from the geothermal system characteristics. Individual flow meters and temperature control valves will measure and regulate flow to the customers.

System Economics

The fossil fuel replacement potential for the Boise Geothermal project is considerable. Assuming a 7,000-gpm flow in the system, utilization of a 50° temperature drop in the water, and a 23 percent system utilization factor, the fossil fuel equivalent is approximately 75,000 barrels of oil per year. Initially, the system is expected to be 100 percent geothermal. Load peaking may be accomplished by building a specific peaking plant for the system at a later date. A de facto peaking system, however, can be accomplished by offering geothermal water to customers on an interruptable basis.

A preliminary system economic analysis has been performed and is summarized in the following table. The results are based upon conceptual design cost estimates. The economic analyses were carried out for four options to provide a basis for comparison:

1. Public ownership of the system built with Department of Energy (DOE) cost-share funding.
2. Public ownership of the system built without DOE cost-share funding.
3. Private ownership of the system built with DOE cost-share funding.
4. Private ownership of the system built without DOE cost-share funding.

The total revenue requirements were calculated for each option, including operating and maintenance expenses, depreciation, debt service, taxes, and, as appropriate, a return on rate base. Engineering for the preliminary and final design has also been included. The DOE cost-share portion of the project was not considered part of the rate base, however. It was used as part of the total investment within the cost base utilized to calculate depreciation. This policy is considered prudent financial management because system revenues that include a provision for depreciation which the City and the District can be used to continually upgrade and replace portions of the systems, as required.

GEOTHERMAL RATE COMPARISON

System		System Capacity (gpm)	Cost of Service: $ per 100 ft^3	Cost of Service: $per Useful Therm
BOISE				
1.	Public Ownership DOE cost-share	2,000	0.75	0.24
2.	Public Ownership No DOE cost-share	2,000	1.50	0.49
3.	Private Ownership	2,000	0.96	0.31
4.	Private Ownership no DOE cost-share	2,000	2.80	0.91
BWSWD				
1.	Public Ownership DOE cost-share	3,000	0.55	0.18
2.	Public Ownership No DOE cost-share	3,000	1.47	0.59

STATUS

Technical Scope

Currently, the scope of the project is as follows:

Boise City

- Production wells to provide 2,000-gpm geothermal water.
- A 1-1/2-mile long transmission line to carry the water between the production wells and downtown Boise.
- A collection pipeline to carry spent geothermal water to a waste disposal system.
- Waste disposal system.

BWSWD

- Refurbish the existing BWSWD Wells 1 and 2.
- Construct new Well 3.
- New transmission pipeline.

The original proposal to the DOE was prepared in July 1978 requesting $9.524 million. Subsequently, DOE notified Boise City and BWSWD that they would consider a cost-share project, with a DOE cost-share of $4.926 million. Subsequently, additional Economic Development Association (EDA) funding and Boise City funding has been identified. In addition, an intensive effort is currently being made to identify and arrange for additional funding from other sources. The scope of the preliminary design has been limited to reflect the current level of funding that has been identified for the project by Boise City, BWSWD, DOE, and EDA. As further funding becomes available, either momentarily or in the future, it is anticipated that the project will be expanded. Design has been carried out to accommodate such future expansion of the systems.

Schedule

The environmental report of the project has been completed and is currently being reviewed by DOE. Initial review of geological data has been completed. A preliminary engineering design report, institutional planning reports, and a preliminary market and rate study based upon conceptual cost estimates have been completed. Currently, additional geological work is being carried out; a drilling plan is being written; and it is expected that siting of the first City and BWSWD wells will take place within the next several months. Drilling should proceed shortly thereafter. It is expected that engineering design of the systems will take place through the balance of 1980 and that initial construction contracts will be bid in the first half of 1981.

Cost

Cost estimates based upon the preliminary design are currently being prepared. Funding sources for the project, in addition to those previously identified, are vigorously being pursued. It is anticipated that the full scope of the project, as currently identified, will be funded in a cost-share arrangement with DOE in approximately the same proportion as originally proposed.

ACKNOWLEDGEMENT

This work has been supported by the Department of Energy, Cooperative Agreement DE-FC07-79ET27053.

PROJECT SUMMARY

Project Title:

Field Experiments for Direct Uses of Geothermal Energy:
Elko Heat Company, Elko, NV

Location:

City of Elko, NV

Principal Investigator:

Mr. Ira S. Rackley, P.E., Project Manager
Elko Heat Company, 702-738-3108

Project Team:

- Elko Heat Company, Elko, NV; Mr. Jim Meeks, President
- Chilton Engineering, Elko, NV; Mr. Ira S. Rackley, P.E., Project Manager, and Mr. Sheldon S. Gordon, P.E., Project Engineer

Project Objectives:

This project was selected to demonstrate the technical and economic feasibility of the direct use of geothermal brines from the Elko KGRA for the purpose of providing space, water, and process heat. In a more general sense, it is the aim of the project to develop information and approaches that will enable the proposers to develop the Elko resource as a viable alternative to the consumption of primary fuels for space, water, and process heating in Elko.

Objectives related to this overall goal are:

- Develop adequate resource information to allow for the design of the geothermal process system.
- Use this resource information to generate a plan for the continued development and use of this resource after the period of government support.
- Displace a significant portion of the primary fuel consumption in Elko for identified energy markets with geothermal energy.

Resource Data:

Resource Area: Adjacent to the Elko KGRA, within the city limits of Elko.

Resource Data (cont'd):

Controlling Geologic Features: Fault zone trending north-northeast through city of Elko; hot water from depth ascending along the fracture zone (see Figure 1.0).

Predicted Temperature: Geothermometry-based predictions (240°F) (actual unknown).

Predicted Flows: Unknown

Depth of Resource: 700 to 2,000 feet, based on cold water well drilling logs (actual unknown).

Fluid Chemistry: Surface flows from existing hot springs are relatively clean (550 ppm - TDS) but may be significantly diluted by ground water.

Design:

The project team has recently started conceptual design work for the project. Due to parallel scheduling of work tasks relating to the confirmation of the geothermal resource (i.e., gradient hole drilling) the present effort of the design team has been directed primarily towards the preparation of an inventory and detailed description of the existing mechanical systems in the three selected buildings.

This effort is the first step in a system design and modeling effort which we feel is somewhat unique. The three selected buildings will be computer modeled using DOE-2, a detailed building loads and system simulation model used to certify compliance to Title 24 of the California Administrative Code - Energy Conservation Standards. The building and process loads description generated by that modeling effort will then be used to drive a modified TRYNSYS simulation of the geothermal distribution system. This modeling effort will allow the design team to look at a number of options for the configuration of the geothermal distribution system and to design a system which may be expanded to meet future geothermal development needs of the community. The modeling tool will also have general applicability to the problems of design and performance estimation for geothermal district and process heating systems. The design team feels that a design tool of this nature will be particularly useful in the evaluation of system economics.

The buildings selected for retrofit to the geothermal source provide a wide variety of system types and configurations. These are described in more detail below. While the diversity of systems has posed a number of problems for the design team, it has also provided the opportunity for the project team to design and test systems for a variety of retrofit applications. This experience will be useful in the effort at continued development of the resource.

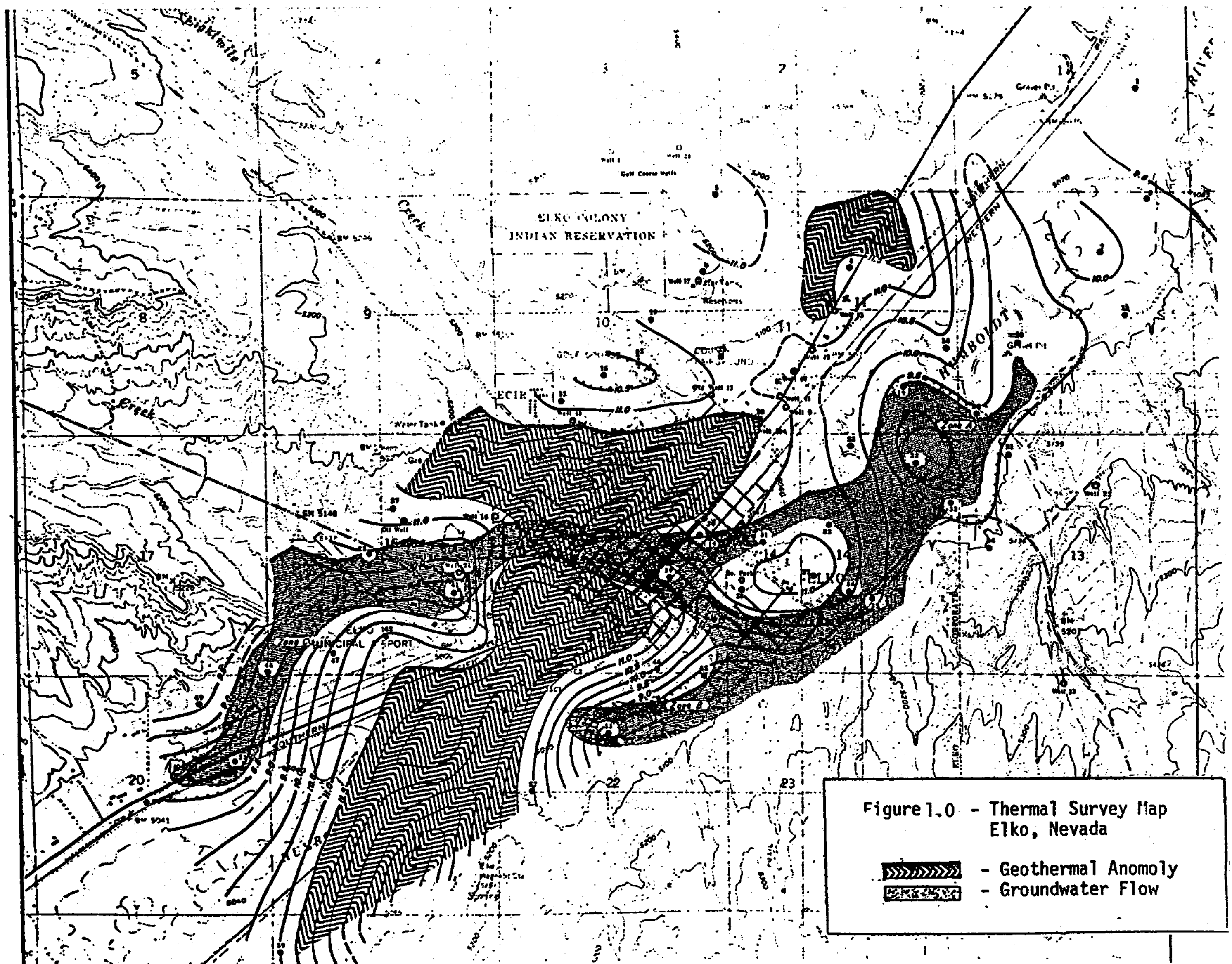

Figure 1.0 - Thermal Survey Map
Elko, Nevada

- Geothermal Anomoly
- Groundwater Flow

Building Systems and Load Summary:

1. Henderson Bank Building

The fifty year old Henderson Bank Building is a four-story, 21,000 sq.ft., brick or stone faced concrete building. The first floor (bank lobby) rises the equivalent of two stories. A mezzanine covers approximately one-third of the floor area and serves as bank office space. The second through fourth floors are office rental spaces. The basement is an unconditioned space and houses the primary energy conversion equipment.

The primary energy conversion equipment applicable to geothermal retrofit is a 200 HP hot water boiler. The boiler is coupled to a perimeter radiation distribution system. Cast iron radiators are located normally at each window. Each radiator is controlled by a thermostat actuated modulating valve.

2. Vogue Laundry

The Vogue Laundry is a 17,300 sq.ft. building. The building construction is tilt-up concrete walls with a 25 ft. high beamed dome, which houses the dry cleaning and laundry facilities. A single story office space fronts the domed building.

Process loads make up the majority of the building energy demand. Internal gains from these process loads supply, in large part, the heat necessary to meet building loads. The primary energy conversion equipment are two 250 HP 125 PSIG steam boilers in parallel. Normally, only one boiler is fired at a time. The 125 PSIG steam is utilized directly by two six and eight boiler commercial flat irons. A hot water generator converts the steam into 175°F hot water which is stored in a 5,000 gallon holding tank. This 175°F hot water is used by six commercial washing machines of a combined capacity totalling 3,130 lbs. Discharged waste water from the washers is run through a heat recovery system to preheat makeup water into the hot water storage tank. Four gas fired hot air commercial tumbler-type dryers finish out the process loads.

The geothermal retrofit will be utilized to heat hot water for the washers. Also, the geothermal source will be used to preheat air via hot water coils for the tumbler dryers. Lastly, hot water coils will be utilized in the little used air distribution system for building heating loads not handled by internal gains.

3. Stockmen's Motor Hotel

The Stockmen's consists of several building components. First is the original motor court building. This is a two-wing, three-story, motel-type building with a heated swimming pool located in the court yard.

Attached to the motor court is the two-story casino/restaurant. The first floor houses the casino/restaurant. The second floor houses air handling equipment and operates as a return plenum. In 1965 a two-story addition was built on top of the casino/restaurant section. These two floors consist of hotel rooms with a large glass-covered atrium court yard in the middle. Another addition was built off the casino/restaurant section in 1973. This two-story addition consists of a showroom, storage area, and four banquet rooms. Underneath the entire building is a basement/garage, which is used as office space, storage, parking, and to house mechanical equipment.

The primary energy conversion heating equipment consists of two 250 HP 60 PSIG steam boilers. Again, these boilers are piped in parallel with usually only one boiler on line at a time. The 60 PSIG steam is used as the main heat transfer medium to the steam coils or hot water generators.

There are several types of distribution systems which corresponds to the various building components. The original motor court is serviced by a modified, two-pipe hot/chilled water system, with individual terminal room fan coil convertors. 180°F hot water is supplied to the system from a steam fired hot water generator. The heated swimming pool utilizes 100°F hot water, again from a hot water generator.

The casino/restaurant is serviced by three air distribution systems and an outside air preheat system. The four systems utilize steam coils for heating. 60 PSIG supply steam is pressure reduced to 10 PSIG at each coil.

The two floors of hotel rooms overhead of the casino/restaurant is serviced by a four-pipe hot/chilled water system. Again, individual terminal room fan coil convertors are utilized. 180°F hot water is supplied from a steam fired hot water generator.

The showroom addition has three types of systems. The majority of space conditioning is supplied by six air handlers. These air handlers are equipped with steam coils which utilize pressure reduced 10 PSIG steam. Two 30 PSIG unit heaters service the storage area. Lastly, a 30 PSIG baseboard system is used to heat a small portion of the addition.

Finally, three air handlers service the underground parking area and mechanical room. These air handlers are equipped with steam coils which utilize either 60 or 30 PSIG steam.

Cooling is accomplished by utilizing two centrifugal water chillers supplying chilled water to the various systems noted above. The feasibility of retrofitting the Stockmen's heating systems will be two-fold. First, all hot water systems will simply be tied into the geothermal source via heat exchangers. Secondly, all steam boilers, distribution piping, and coils will be retrofitting to hot water and connected to the geothermal source. This will be a major undertaking and requires extensive repiping, especially concerning the return system.

System Economics:

No effort has been made at this time to update the discussion of economics presented in the initial program proposal submitted to USDOE. The project team feels it would be premature to develop a system economics evaluation until the resource is confirmed and the conceptual design has progressed beyond preliminary drawings. For this reason, no system economics are available for this printing.

Project Status:

1. The Elko Heat Company project is nearing the completion of Phase IA. - Resource Assessment. Gradient wells are presently being drilled on two sites identified as promising in the thermal survey work. We expect to present some preliminary resource information at the El Centro meeting.

As stated earlier, authorization to begin certain conceptual design tasks has been received and this work is proceeding on a parallel schedule with the drilling program.

The technical approach of the project has not changed from that initially presented in proposal documents and no significant changes to the work scope are anticipated at present.

2. Schedule. The project is presently three month behind schedule, primarily due to a one month slippage on the project start date and delays encountered in the review and negotiation of the gradient well contracts. The project team is hopeful that some of this slippage will be reduced by running conceptual design tasks in parallel with the drilling program.

Schedules for the project are shown in Figure 2.0, where it can be seen that the project has not yet reached its first major milestone, resource confirmation.

3. Cost. Project costs to-date have been below or at levels described in the initial cost proposal to USDOE. Cost share agreements, as initially proposed, are still in effect.

Costs for Phase III - Fabrication will be revised at the end of the Conceptual Design Phase. It is the concern of the project team that extensive retrofitting of existing mechanical systems may increase costs above those projected in the initial proposal. This information is presently being developed.

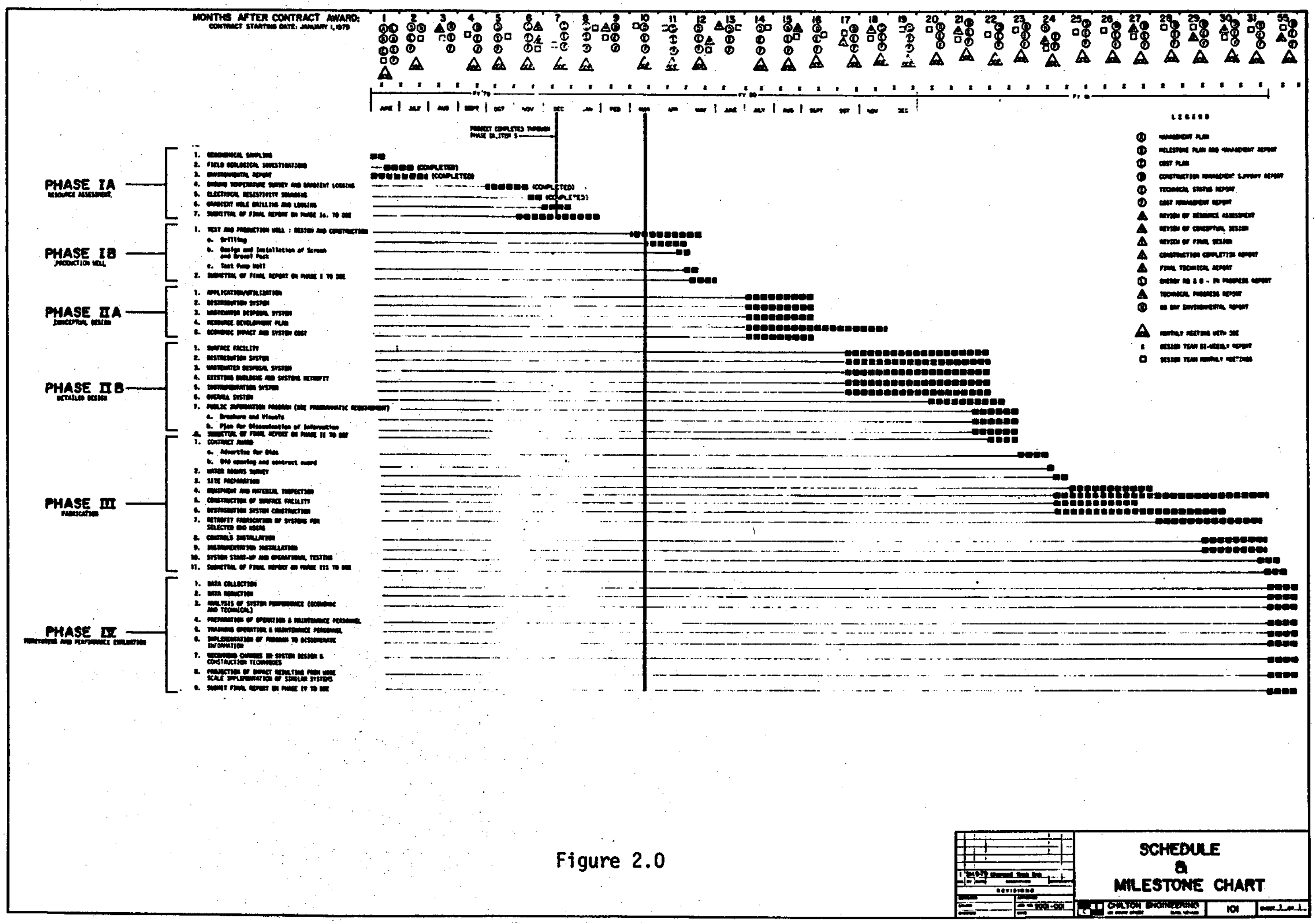
MONTHS AFTER CONTRACT AWARD:
PHASE IA
PHASE IB
PHASE IIA
PHASE IIB
PHASE III
PHASE IV
SCHEDULE & MILESTONE CHART
CHILTON ENGINEERING

Figure 2.0

KLAMATH FALLS GEOTHERMAL DISTRICT HEATING

I. PROJECT DESCRIPTION

The following is a summary of the Conceptual Design Report and the proposed Geothermal Heating District Project awarded to the City of Klamath Falls under PON EG-77-N-03-1553 to the City of Klamath Falls, Oregon to design, construct and initiate operation of a geothermal space heating district. The district utilization project is for a City owned and operated system serving 14 city, county, state and federal office buildings. The project is essentially broken down into three phases which include establishment of wells, construction of a distribution line and the retrofiting of the existing buildings.

The production area to produce the geothermal waters for the heating of the district is to be in the vicinity of the Old Fort Road area which is further described in the Conceptual Design Report. The production area is located within the second largest KGRA, as reported by the U.S. Geological Survey. The project will involve two production wells of approximately 1,000' deep with an estimated production of 500 gallons per minute each. The anticipated temperature from the production wells is 220^{o} F, and the required flow for the 14 buildings is 768 gallons per minute. The estimated peak load for the 14 buildings is 15.326 x 10^6 BTU per hour.

Each production well will be outfitted with a 75 h.p. turbine pump with variable speed drive. Each well and pump will be enclosed by a 10' x 10' well head building. The geothermal waters will be transported 4,060' to the vicinity of the County Museum and the City Fire Station. The geothermal waters will be transported by single 8" diameter steel pipe with urethane wrap insulation and placed in a concrete tunnel. The tunnel will be 58" x 38". The tunnel will be installed in 10' sections with removable tops for easy maintenance and future expansion. The tunnel will be placed in existing public rights-of-way and, wherever possible, will become a part of the sidewalk surface that currently exists.

The concrete tunnel was chosen for the following reasons:

1. It will provide a sterile environment, eliminating outside corrosion factors which, through past experience, has been the main corrosion factor in the Klamath Falls area.

2. Provide for an extended life cycle period from 20 years to 70 years.

3. Provide easy accessibility for maintenance in the future.

4. The tunnel is designed for easy expansion for future pipe lines for distribution of the resource into the other parts of the urban area.

The steel pipe in a concrete tunnel is insulated with 2 in. of rigid fiberglass insulation (K - .32 BTU-in/ft^2 - ^oF - hr) and the buried steel pipe in an FRP protective covering is insulated with 2 in. of urethane foam (K - .25 BTU-in/ft^2 - ^oF - hr).

Expansion of the steel pipe is controlled by "Flexionics" expansion joints (bellows type). Flexionics controlled-flexing expansion joints take pressures up to 300 psi and have temperature limits of -20 to 800^{o}F. These units may be either single or dual acting with welding ends. The dual expansion joints are furnished with an anchor base and can be employed for application where large amounts of any combination of the three basic movements, i.e., axial movement, lateral deflection and angular rotation, cannot be absorbed by a single expansion joint.

Bellows type expansion joints were selected over expansion loops because of the limited space available in developed streets, less head loss and cost effectiveness.

At the end of the geothermal line, a centralized heat exchanger building 30' x 40' will be used to house two plate heat exchangers. The two plate heat exchangers will then transfer the heat from the geothermal line to a closed loop domestic water line. In addition to the two heat exchangers, a heat exchange building will include two vertical turbine circulation pumps of 50 h.p. capable of pumping 400 gallons per minute each. To handle surges and expansions, a 1,000 gallon pressure and surge tank will be housed at the central heat exchange building. A telemetry system controlling pumping requirements, heating requirements and the appropriate flow for those requirements will be the basic control system which also will be housed in the central heat exchange building.

The control system for the project is outlined in the attached Figure 1 and described as follows:

1. The flow in the primary geothermal fluid supply line is regulated by the pneumatic butterfly valves (V-1 and V-2) located on the reject side of the heat exchangers which are controlled by outside air temperature (T_1) temperature (T_2) via Receiver-Controller #1. Closing of control valves V-1 and/or V-2 results in increased pressure in the primary supply line which in turn is relayed to a pressure control regulator located at the production pump, reducing the pumping rate of the variable speed/fluid drive deep well vertical turbine pumps (TP1 and TP2). A reduction in pressure due to opening of valves resulting from a drop in outside air temperature (T_1) and geothermal return fluid temperature (T_2) causes the pressure controller to increase the pumping rate.

2. The flow in the secondary closed loop is regulated by the temperature and pressure difference between the supply and return lines. The most remote point in the system, at the County Courthouse complex, will be the critical location. In order to provide sufficient heat to subscribers, the pipe temperature loss to this point will be kept to a minimum of .3^{o}F and the pressure to a minimum of 60 psi.

- DISTRIBUTION NETWORK CONTROL

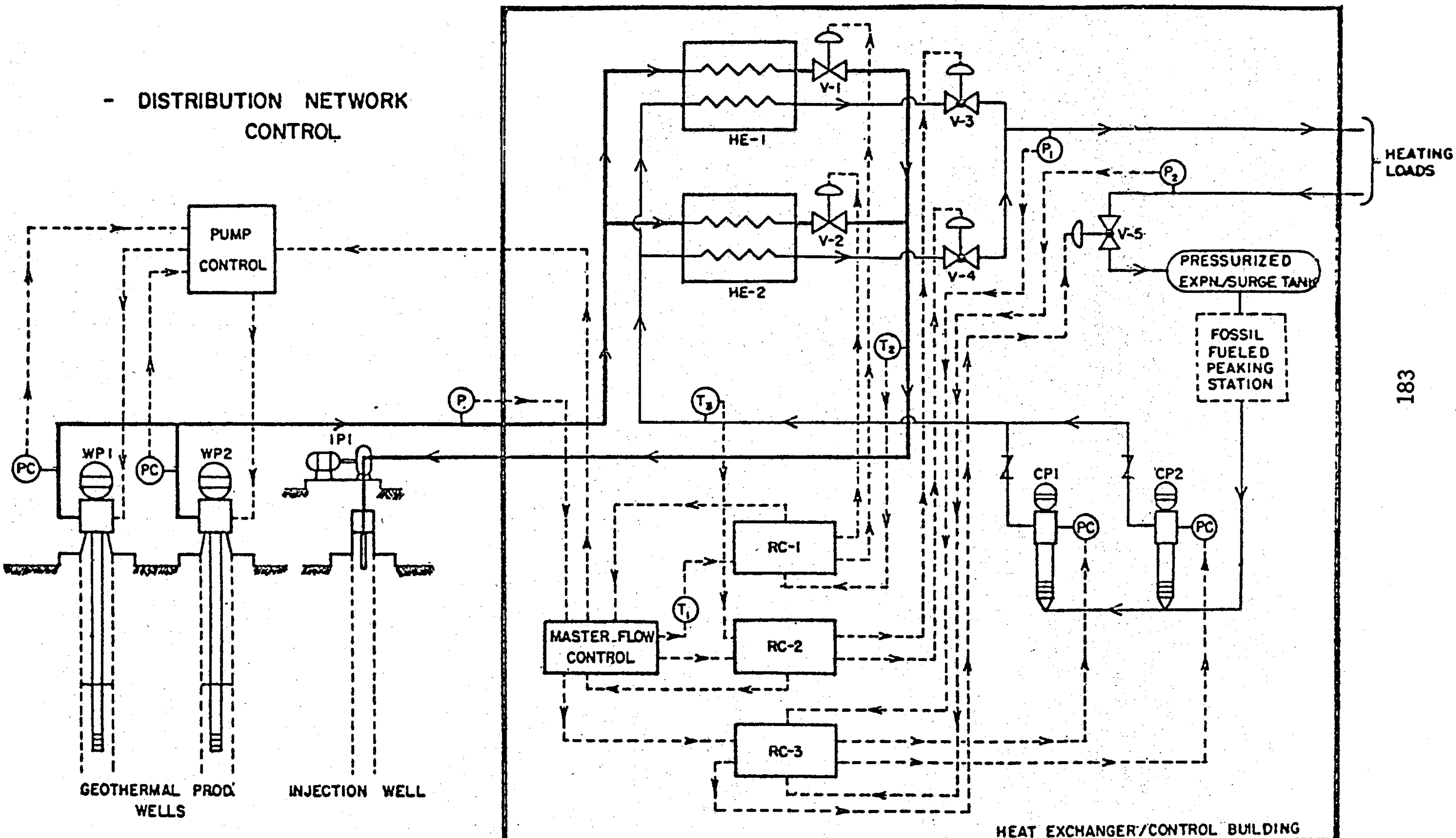

Figure 1.

3. The supply temperature in the closed secondary loop is controlled on the basis of measured outside air temperature (T_1) and heating water return temperature (T_3). Receiver-Controller #2 will activate pneumatic globe valves V-3 and/or V-4 to open when outside air temperature (T_1) and heating water return temperature (T_3) drop. The result is a reduction of pressure in the heating water supply (P_1) and return (P_2) line, causing an increased pumping rate of the variable speed/fluid drive vertical turbine circulation pumps (CP1 and CP2).

4. Receiver-Controller #3 regulates the pressure in the closed loop network through the balancing globe valve V-5 when sensing supply pressure (P_1) and return pressure (P_2). This assures that design pressures are maintained to subscribers.

5. Failures in pumps or pipelines and unusual flow rates, temperatures or pressures will be monitored by a master flow controller (MC1). This includes the pressures in the pipeline as well as the expansion tank. The master flow controller, under these circumstances, will shut down the pumps in either pipe system and sound an alarm in the heat exchanger/control building. This alarm will be monitored in the Fire Station.

6. Examples of possible critical situations would be a "fully open" indication from a control valve under low heat load conditions; a reduction in pipeline pressure under high pumpting rates (due to a rupture); or a drop in supply temperature (caused by a closed valve or stopped pump).

After the geothermal waters have circulated through the two steel plate exchangers, the water will be reinjected into an existing well in the vicinity of the County Museum. The centrifugal injection pump of 20 h.p. will be installed for injection.

The closed loop domestic pipe will supply the fourteen buildings at an estimated temperature of 200° F. The line will consist of 8", 6" and 3" RFP pipe which will be directly buried along the pipe route.

The secondary line will then provide service to the U.S. Post Office, State Employment Office, State Welfare Office, City Hall, City Hall Annex, City Jail, County Courthouse, Veterans Memorial Building, County Jail, County Courthouse Annex, County Library, County Courthouse Extension, County Museum and City Fire Station.

The capital cost of the intended system is as follows and more detailed costs are attached in Figure 2.

A.	Wells and Well Head Equipment	$ 169,772
B.	Pipe Lines	835,293
C.	Heat Exchanger Facilities	197,506
	Subtotal	$ 1,242,571
D.	Engineering and Inflation	197,429
	TOTAL	$ 1,400,000

TOTAL COST SUMMARY

Case Ia
(8", 6" Steel Pipeline on Concrete Tunnel)

Item	Cost	
A. Wells and Well Head Equipment:		
1. Production well (2) @ $38,898	$ 77,796	1(B)
2. Production well pumps (2) @ $41,988	83,976	1(A)
3. Well head buildings (2) @ $3,500.	7,000	1(B)
4. Power hook-up in buildings (2) @ $500	1,000	1(B)
Subtotal	$ 169,772	
B. Distribution Piping Network:		
5. Primary supply pipeline (8" steel in concrete tunnel) . . .	506,175	1(B)
6. Secondary supply pipeline (8", 6" & 3" FRP Direct burial)	329,118	1(B)
Subtotal	835,293	
C. Heat Exchanger Building:		
7. Plate heat exchangers (2) @ $14,000	28,000	1(A)
8. Control system, wiring, etc. (basic)	44,537	1(B)
9. Circulation pump (2) @ $13,691	27,382	1(A)
10. Expansion/surge tank	5,000	1(A)
11. Building, including installation of equipment	90,000	1(B)
12. Injection well (museum)	-	
13. Injection well pump	2,587	
Subtotal	$ 197,506	
Total Equipment & Installation Costs	$ 1,202,571	
D. Overhead Costs:		
Admin. & Engineering @ 10%	120,260	1(C)
Contingency (inflation @ 5%)	77,169	1(D)
Total Cost	$ 1,400,000	

Figure 2.

The estimated equivalent annual cost of capital for this system, based on a 20-year life and 6.5% interest, with the inclusion of operation and maintenance costs, are $201,601. Using an expanded system heat load for 11 commercial blocks, the estimated cost of the geothermal energy is $0.29/therm through a 20-year period. The equivalent annual cost for natural gas over the same 20-year period is $662,291, which is based on Oregon Department of Energy projections. This amounts to an average annual cost of natural gas of $0.94/therm, or 335% higher than geothermal.

The project size and future plans for the Geothermal Heating District calls for expansion to both commercial and residential users. Such expansion, in all likelihood, shall be predicated on voter approval for bond issues for construction funding.

II. STATUS

The City has currently completed the drilling of two production wells. Well #1 has been drilled to a depth of 360' and cased with 12" casing. The pump test has been concluded with the results of 224° F water and 780 gallons per minute. The static water level drop at the 780 gallon per minute pumping rate was 70'.

Well #2 has been completed to 900' with the producing zone from 190' to 240'. The original intent of Well #2 was to break through the lower aquifer and intercept deep aquifer. In drilling to 900', no indication was found of the deep aquifer, so the 190' to 240' zone was perforated with flows not being determined at this time. Temperature gradients indicate 225° F with heavy flows in that production zone.

The major milestones contemplated within the project were the construction of the wells, installation of the geothermal line, construction of the heat exchanger building and construction of the distribution line.

The following are the currently proposed start up and completion dates for each of the major milestones.

	Start Up	Completion
Construction of Wells	8/79	1/31/80
Installation of Geothermal Lines	12/15/79	8/15/80
Construction of Heat Exchanger Bldg.	4/30/80	8/15/80
Construction of Distribution Lines	4/30/80	10/31/80

III. COST

The costs, as reiterated herein, for the project are still current based on existing knowledge. We have explored the cost with various suppliers, and they have indicated that we are still in line with today's market.

The only real cost vs. actual expenditure to be related at this time is for the production wells. As stated in the Cost Summary, the production well estimate is $77,796. The City has drilled two production wells and also abandoned one well where equipment was lost and not able to be secured from the well. The estimated cost of the production wells is to be $65,000.

The City was able to obtain a cost saving by implementing a program where it leased the drill rig, hired licensed drillers and purchased supplies such as casing and drilling mud directly. The City did bid the drilling of the wells on a normal contractual basis and the bids received were in excess of $135,000.

DISTRICT SPACE HEATING SYSTEM FOR PAGOSA SPRINGS, COLORADO

Presented at the

Geothermal Direct Heat Applications Program

Semi-Annual Review Meeting

El Centro, California

April 15, 16, 17, 1980

I. PROJECT DESCRIPTION

A. Resource

The geothermal resource in Pagosa Springs has been used on an individual basis since the early 1900's. Since then, nearly 30 wells have been drilled for heating and recreation purposes. These wells are drilled to depths of less than 500 feet and produce waters ranging in temperature from 120°F to 150°F.

Based on data from existing wells in the production area, each production well for the project is anticipated to produce 1000 gpm of geothermal fluid at 140°F. The producing zone for these wells will be between 240-300 feet of depth. All new production wells are to be separated by 300 feet to minimize local interference on existing wells.

Water samples were analyzed from several of the wells and natural hot springs. A representative sampling of the chemical analysis is presented below. Based on these chemical analyses, the geothermal fluid requires no special treatment for corrosion or scale prevention.

Determination (mg/l)	County Well #1	Edmonds Well	Methodist Church	Town Well	Spring
pH	6.7	6.6	7.1	7.0	7.1
Conductivity (μmhos/cm)	4270	4040	4380	4260	4090
Calcium	240	240	310	270	270
Magnesium	22	22	25	23	23
Sodium	640	670	680	670	670
Potassium	87	87	86	87	86
Iron	0.07	<0.05	1.11	0.19	0.14
Silica (as SiO_2)	61.4	62.3	59.0	58.2	63.0
Alkalinity (as $CaCO_3$)	670	630	720	620	660
Carbonate (as CO_3)	0	0	0	0	0
Bicarbonate (as HCO_3)	810	760	870	750	800
Sulfate (as SO_4)	1520	1430	1530	1730	1680
Chloride	160	160	160	150	155
Nitrate (as N)	0.09	0.04	<0.04	<0.04	<0.04
T.D.S.: (@180°C)	3160	3120	3200	3100	3130

B. Design

The district heating system of this project will provide heating for 10 public buildings, 54 businesses, and 63 residences. These users are primarily located along U.S. Highway 160, running east to west through the town. The distribution system parallels this road and is illustrated on Figure 1.

For the proposed closed distribution system, two independent loops have been designed, one for the east side of town and the other for the west side, to provide a safety factor in the event of a pipeline breakage. The east loop is designed to carry 1350 gpm. The west loop has been designed for 1000 gpm; however, initially it will carry only 500 gpm. This is to permit future expansion of the distribution system into the growth areas of Pagosa Springs. A schematic diagram of the overall design is shown on Figure 2. Briefly, the system will operate as follows:

1) Clean city water will be heated with the geothermal fluid, using two plate heat exchangers. The geothermal fluid leaving the plate heat exchangers is then discharged to the San Juan River.
2) The clean heated city water will be circulated in each of two closed loops by means of one to four pumps, depending on user demand. Each of the loops consists of large diameter pipes, 6 inches to 10 inches, referred to as trunklines, and smaller diameter pipes carrying the fluid to the individual users. Two parallel trunklines are in each loop. An insulated supply trunkline carries the warmed circulating fluid and an uninsulated return trunkline directs the cooled circulating fluid back to the heat exchangers.
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4) The circulating fluid is collected in the return trunkline and then routed to the heat exchangers, where the entire process is repeated.

Since the geothermal flow from old wells is to be replaced with flow from new wells, there will be no new incremental flow into the San Juan River. Thus, the State of Colorado has agreed that the geothermal fluid may be discharged into the San Juan River.

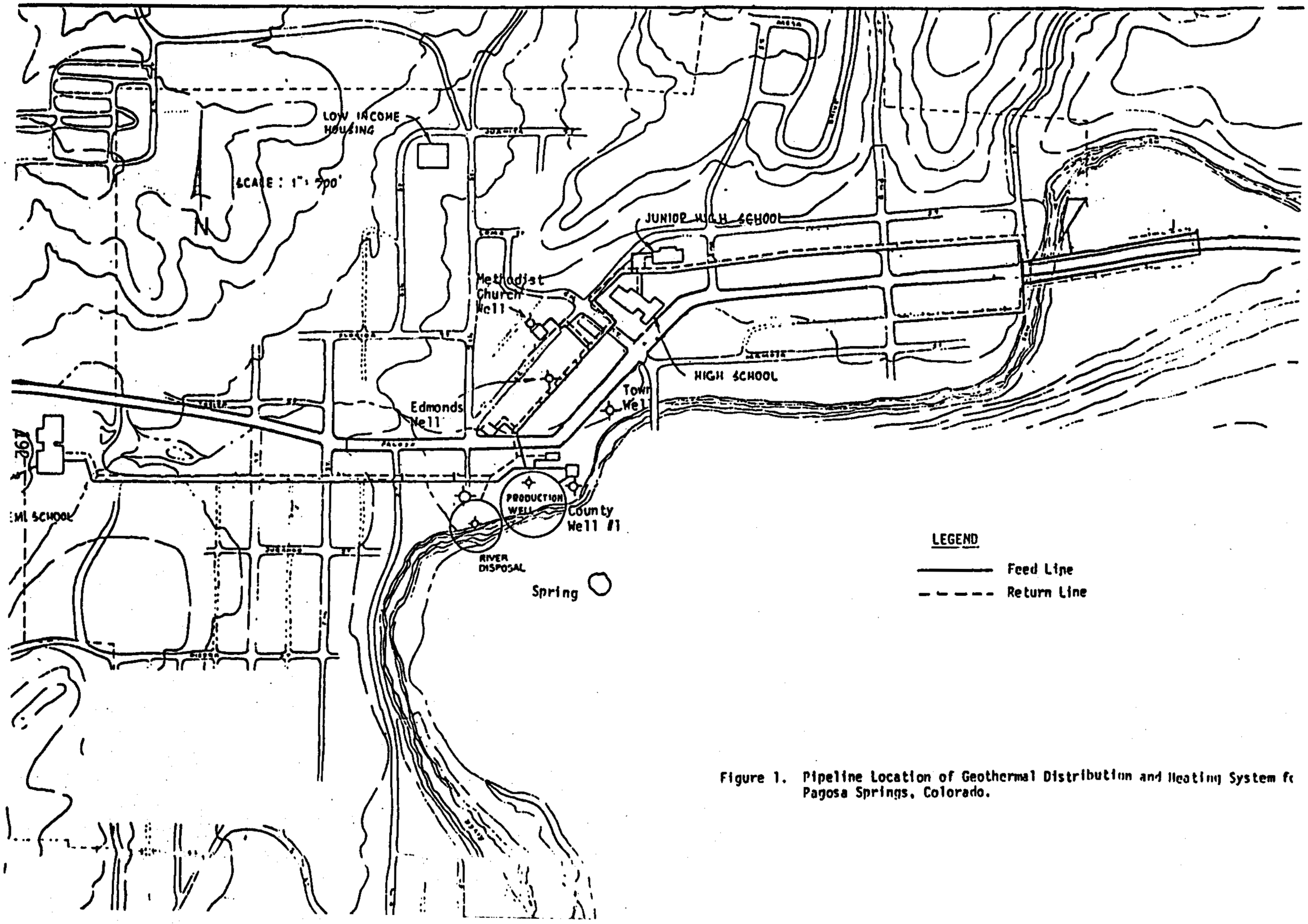

Figure 1. Pipeline Location of Geothermal Distribution and Heating System fc
Pagosa Springs, Colorado.

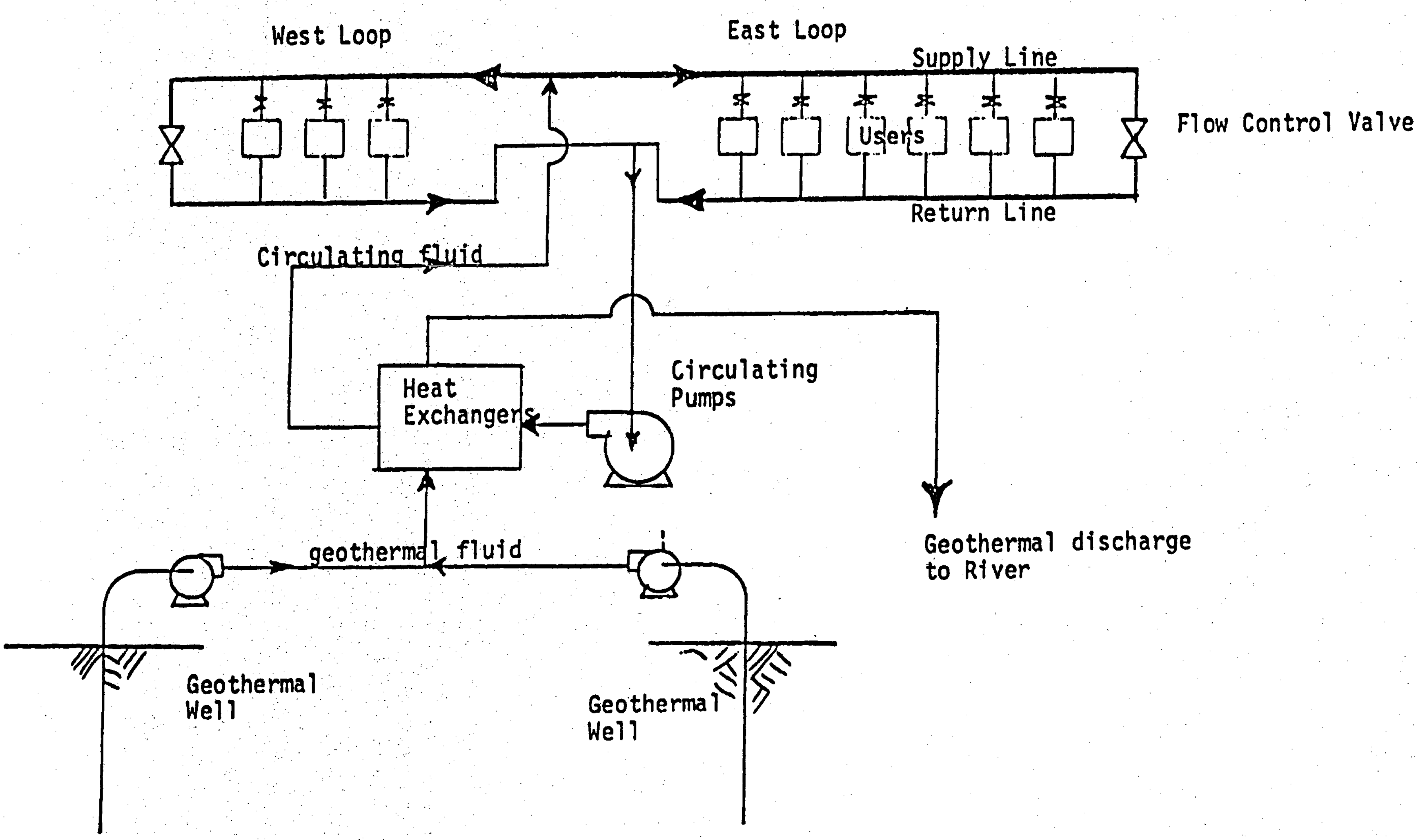

Figure 2. Schematic Diagram of Heating System

C. System Economics

The district heating system will supply an annual heat load of 56.7×10^9 BTU/yr which is equivalent to about 9500 bbl/yr of oil. The heating system is designed for a capacity of 27 million BTU/hr. This design load is sufficient to meet the peak heating requirements of all users.

A public entity will operate the system and revenues generated from the project will be used to pay for operating and maintenance costs of the system. In addition to the operating and maintenance costs a small revenue shall be collected for future expansion of the heating system. The annual fuel cost savings to all users is estimated to be $50,000 annually.

The expected heat to be used on an annual basis for the first three years of operation is 28×10^9 BTU/yr. Using this annual heat load and the $56,800 operating costs, which includes $20,000 repayment to DOE, the system could sell heat for $2.03/million BTU. This value is compared to other heating alternatives in Table 1. The cost for fossil fuels is on a delivered usable basis.

Table 1. Energy Costs for Geothermal and Other Alternatives at Pagosa Springs

Heat	Cost $/Million BTU
Geothermal	2.03
Natural Gas	3.85
Propane	7.62
Electric	13.04
Wood	~2.25

As seen from the table, the cost for geothermal heating could be increased above the operating and payback costs and yet still be attractive when compared to the other alternatives.

II. STATUS

A. Technical Scope

The scope of the project has been enlarged from the original proposal without significantly increasing the cost of the project. This is due primarily to the identifying of additional users along the pipeline route. Table 2 shows the difference in number of users, design flow rate, and annual heat load between the proposal and the present design.

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	Proposal	Present Design
NUMBER OF USERS		
Public Buildings	12	10
Businesses	22	54
Residential	23	63
DESIGN FLOW RATE IN GALLONS PER MINUTE		
Public Buildings	392	379
Businesses	372	1055*
Residential	138	378
Totals	902	1812
ANNUAL HEAT LOAD IN 10^6 BTU/YR		
Public Buildings	12,400	11,800
Businesses	11,900	33,000
Residential	4,300	11,800
Totals	28,600	56,700

*Includes an additional 100 gpm not accounted for in survey.

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2) The original proposal had called for the direct utilization of the geothermal fluids for the heating medium. However, the decision was made by the advisory committee that a clean circulating fluid should be used. Thus a closed loop heating system has been designed utilizing supplementary heat exchange equipment. This equipment was not expected to be necessary when the proposal was prepared.

B. Schedule

The original schedule called for operation of the heating system during 1980-1981. This time frame is still anticipated. However, the design and construction phases of the project were set back 6 months due to contractual delays. Additional time slippages have been realized due to the necessity of drilling new production wells. The major milestones for the project are now scheduled as presented below.

1) Resource confirmation - June 1980.
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C. Costs

The total cost of the project is estimated at $1,003,000, of which DOE will provide $779,000 and local community $224,000. The amount shared by the local community is comprised of in-kind contributions of wells, rights-of-way, easements, and work by local people. The Town of Pagosa Springs has been designated as the local lead entity by its partners, Archuleta County and the School District. Local control is, by agreement among the three entities, handled by an advisory committee consisting of interested and qualified citizens.

Table 3 shows the cost breakdown from the original proposal and current design. The changes in costs of the project are due primarily with the decision to go with a closed loop heating system and the significant number of new users. Additionally, the wells drilled by the Colorado Geological Survey and those available to project are insufficient for the system needs.

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The additional costs can be attributed to the need for heat exchange equipment and new geothermal production wells. However, these costs are partially offset by the money originally allocated for a reinjection well and the reduction in the cost estimate for the pipeline.

COURY and ASSOCIATES, INC.
CONSULTING ENGINEERS
GEOTHERMAL PRODUCTION AND UTILIZATION
WATER: REUSE, DESALTING, DISPOSAL
H_2S CONTROL • ALCOHOL PRODUCTION

7625 WEST 5th AVENUE
LAKEWOOD, COLO. 80226

(303) 232-3823

March 24, 1980

Mr. G. S. Budney
Energy Programs Office
Energy Technology Engineering Center
P.O. Box 1449
Canoga Park, CA 91304

Dear Mr. Budney:

Enclosed is the copy of the Pagosa Springs project description. If anything appears to be missing, or if there are questions, please give me a call.

Sincerely,

Ken Garing

Kenneth L. Garing

Enclosure

KLGaring:fkw

DISTRICT SPACE HEATING SYSTEM FOR PAGOSA SPRINGS, COLORADO

Presented at the

Geothermal Direct Heat Applications Program

Semi-Annual Review Meeting

El Centro, California

April 15, 16, 17, 1980

I. PROJECT DESCRIPTION

A. Resource

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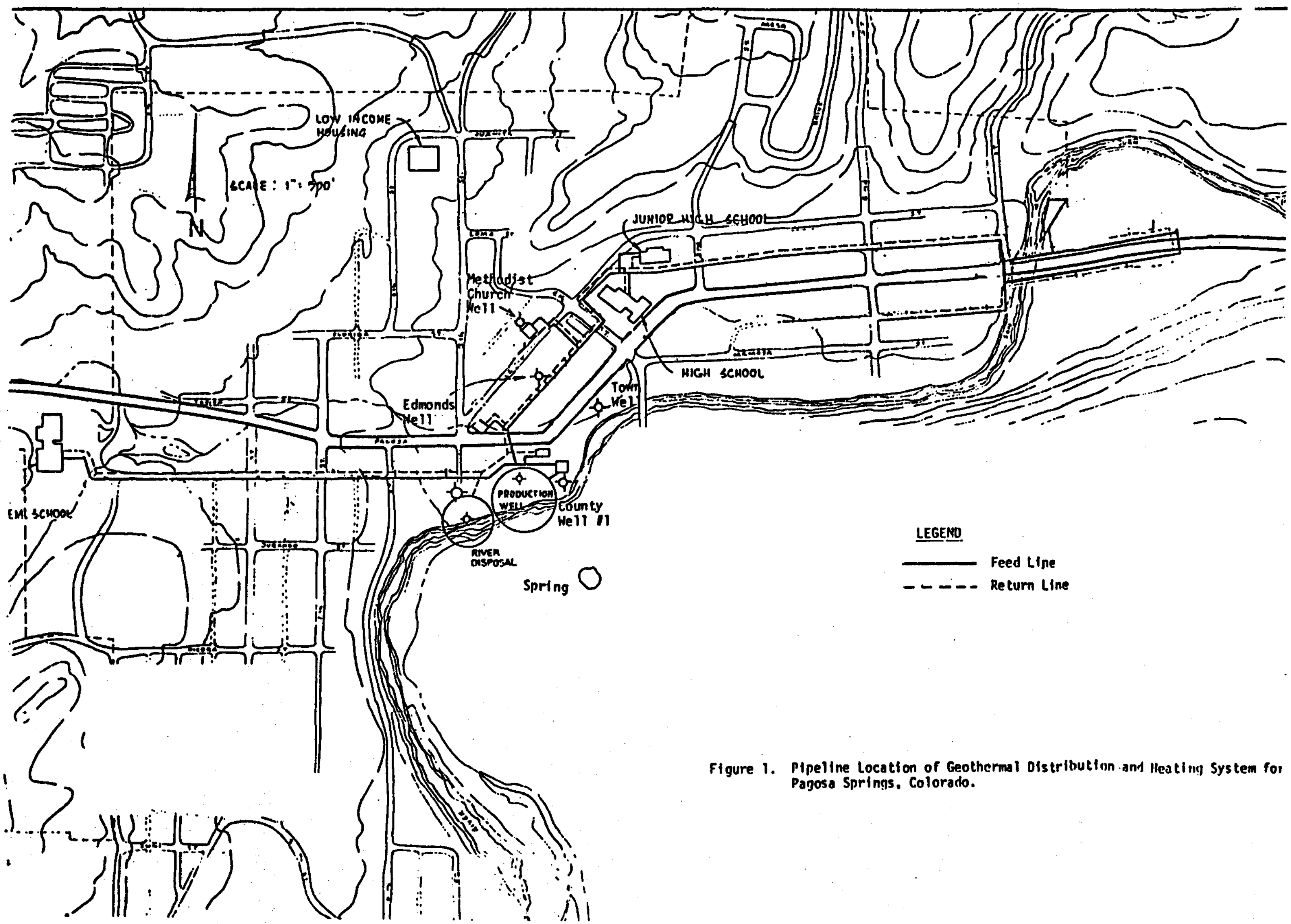

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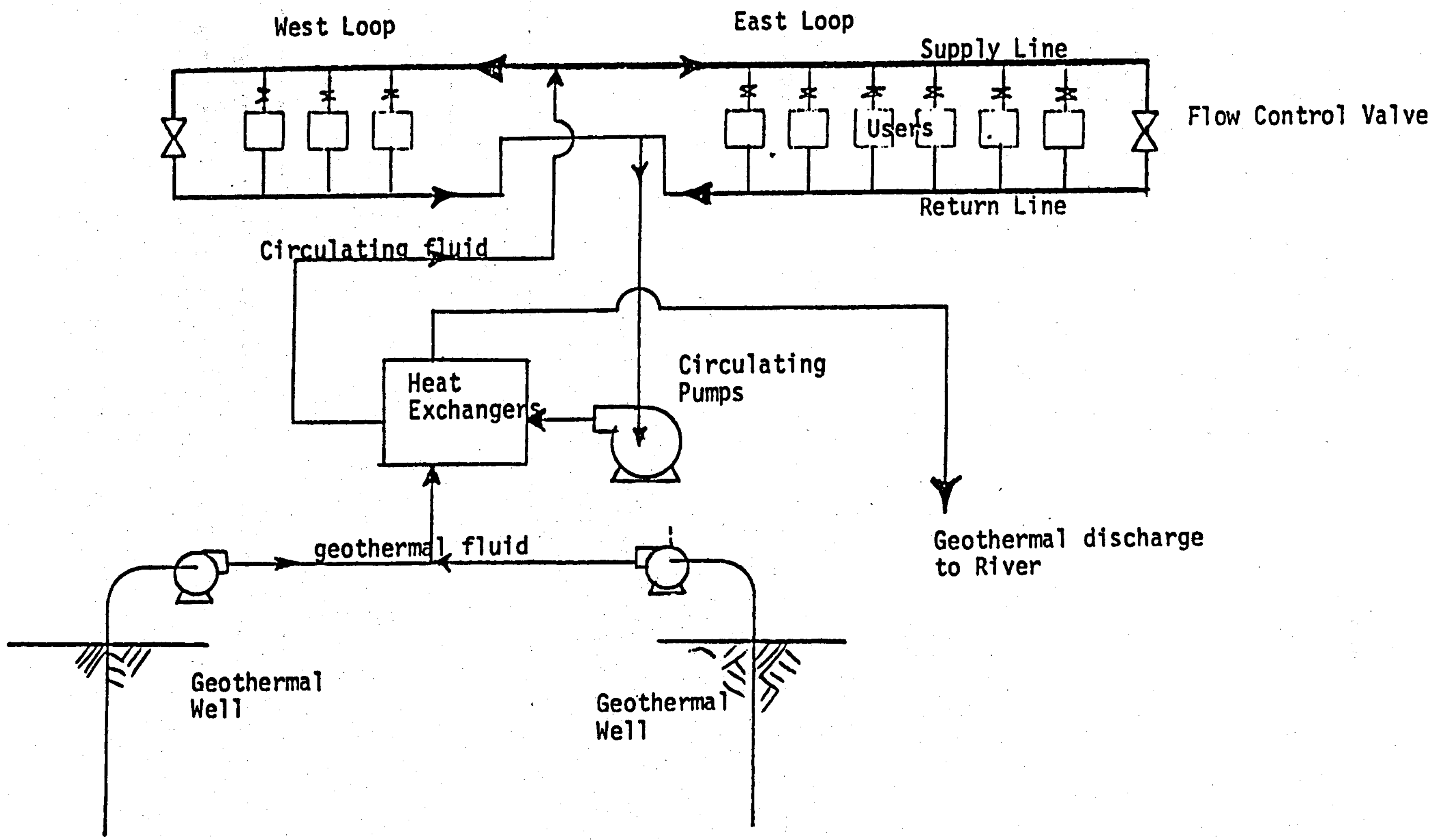

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Klamath County YMCA

(Input not received in time for printing)

NAVARRO COLLEGE

Highway 31 West
Corsicana, Texas 75110

Phone 214-874-6501

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR SPACE AND WATER HEATING AT NAVARRO COLLEGE AND NAVARRO COUNTY MEMORIAL HOSPITAL AT CORSICANA, TEXAS

TOTAL CAPABILITY PROJECT TEAM

Prime Contractor:	Navarro College, Corsicana
Principal Utilizer:	Navarro County Memorial Hospital, Corsicana
Geothermal Consulting Engineers:	Radian Corporation, Austin
HVAC Consulting Engineers:	Ham-Mer Consulting Engineers, Austin
Drilling Consultant:	N. H. Hardgrave, Corsicana
Tubing:	Armco Steel, Houston
Financial:	Wolens & Irwin, Corsicana

Navarro College
Corsicana,Texas

I. PROJECT DESCRIPTION

Resource

The Ouachita fold belt which underlies much of the Texas Gulf Coastal Plain and West Texas is the source of heat at the project site in the Navarro County area located about 60 miles south of Dallas. The Mexia-Talco fault system provides a pathway for the hot water from these deeper rocks into the shallower water producing formations near Corsicana. The Woodbine Formation is the shallowest hot water producer in the area at a depth of about 2,100 feet at Navarro College. Sandstones and limestone of the Trinity Group are capable of yielding various amounts of water from depths of about 3,400 to 5,000 feet in the Corsicana area. The Hosstan Formation underlies the Trinity Group and rests in the deeper Ouachita fold belt. The complex faulting associated with the Mexia-Talco fault system and lack of historical geothermal production makes prediction of the water temperature in the Woodbine Formation difficult. However, based on information gathered from the Texas Railroad Commission records and individuals familiar with the subsurface strata in the Corsicana area, the Woodbine sand formation was selected as the prime candidate for drilling. Geothermal fluid at 135°F has been produced from that formation for oilfield waterflood operations east of town,

As part of the Navarro College cost share geothermal Well No. 1 was complete into the Woodbine Formation on the campus. Table 1 shows important well test parameters. The casing was shot perforated between 2,450 and 2,550 feet. The well was originally anticipated to produce 400 gallons per minute (gpm) of fluid at 135°F. However, greater than expected drawdown resulted in a lower output from the pump. Water from the Woodbine No. 1 well at Navarro College has been analyzed and the results of the analysis is presented in Table 2 along with analyses of water from the Woodbine at two other wells in the area.

TABLE 1. RESULTS OF GEOTHERMAL WELL NO. 1 TESTING

Depth, BLS	2664 Ft.
Static Fluid Level, BLS	421 Ft.
Pump Set Depth, BLS	1000 Ft.
Drawdown Fluid Level, BLS	777 Ft.
Pump output	315 gpm
Temperature, Surface	125°F
TDS (Total Dissolved Solids)	5860 ppm

BLS = Below Land Surface

TABLE 2. CONCENTRATIONS OF CHEMICAL CONSTITUENTS IN WATER FROM THE WOODBINE FORMATION NEAR CORSICANA (all units except pH are mg/1)

	Woodbine[1] at Corsicana	Woodbine[2] East of Corsicana	Woodbine[2] Navarro College Well No. 1
Ca	13	96	13
Mg	5.4	420	5.6
Na	1,810 (Na + K)	6,100	2,020
HCO_3	1,580	1,250	1,140
SO_4	153	<5	38
Cl	1,790	8,700	2,560
F	2.5	1.05	--
TDS	4,550	15,000	5,300
Hardness, $CaCO_3$	55	--	--
pH	--	8.0	--
Temperature (°F)			125

[1]From Thompson, Gerlad L., Ground-Water Resources of Navarro County, Texas.

[2]Analyses performed by Radian Corporation.

Following the Well No. 1 production test the need for a hotter resource was seen in order to reduce pumping costs and flow rates. It was proposed to extend the planned Woodbine injection well No. 2 to a depth sufficient to penetrate the Travis Peak Formation estimated to be around 4,700 feet below land service. Well No. 2 test hole was drilled to 4,760 feet total depth and Repeat Formation Tests showed no water production at three candidate levels below 4,500 feet. The hole was plugged back to 4,100 feet and eight inch casing was cemented to the surface. Maximum temperature in the well has been measured at 158°F. A candidate interval has been perforated from 3,906 to 3,932 feet and a small artesian flow has been realized, however, the production capacity of this zone is yet to be determined through greater perforation and pumping. Preliminary fluid quality data are shown in Table 3. Investigations are underway to determine the corrosion and scaling characteristics of this high TDS fluid.

TABLE 3. PRELIMINARY FLUID ANALYSIS OF NAVARRO COLLEGE WELL NO. 2

Component	Value
pH	7.4
Temperature, Surface	95°F
Temperature, Bottom	158°F
Conductivity	38,000 μ mho·cm
	mg/ℓ
TDS	24,000
TSS	64
Ca	440
Cl^-	9,950
CO_3^{-2}	<1
Cu	0.04
Fe	37
HCO_3^-	293
K	40
Mg	140
Na	6,980
OH^-	1
SO_4^{-2}	5,500
Zn	4.5

Design

This project will retrofit the Navarro College Student Union Building and the Navarro County Memorial Hospital water and space heating systems to use geothermal energy to reduce the consumption of fossil fuels at the facilities. Modern energy convervation measures will also be implemented in the program to first reduce energy consumption. The geothermal fluid distributed to the Hospital and Student Union Building will be supplied from the Navarro College well using a submersible pump. The originally proposed conceptual design of this system is presented in Figure 1. The geothermal fluid flows to both the Hospital and the Student Union Building during the day and at night the flow to the Student Union Building will be cut off while it is unoccupied and the entire flow will be used to heat the domestic water, preheat the fresh air intake and provide space heat for the Hospital. During the day heat input from the geothermal retrofit to the air preheating loop at the Hospital will decrease. The geothermal system at the Student Union Building will be used to heat domestic water and provide space heating. The spent geothermal fluid from both the Hospital and College will be injected at a well located on college property. The location of the wells in relation to the facilities is presented in Figure 2.

As a part of the geothermal retrofit program modern energy conservation measures will be implemented at the Student Union Building and the Hospital. A variable air volume control to minimize mixing of hot and cold air for the heating and air conditioning system serving the nursing wing and administrative area of the Hospital will be incorporated into the retrofit. This modification will reduce the total energy requirements (and geothermal load) at the Hospital.

System Economics

The energy conservation measures at the hospital will reduce the natural gas consumption by approximately 4,500 MCF per year, which in turn will result in a comparable Btu reduction in the electrical cooling requirement. At the Student Union Building, 26 percent of the natural gas that is conserved is used for domestic water heating and 74 percent is used for space heating. At the hospital, 16 percent of the natural gas consumed is used for domestic water heating and 25 percent is used for space heating (the remaining 59 percent is required for reheat and other uses). The retrofit geothermal heating system will display about 7300 MCF per year of natural gas total for the college and hospital if the No. 1 well 125°F fluid is used. Therefore, the total project will display a total of 16,300 MCF of natural gas or 1,920 bbl of oil per year.

As is seen later in Section II, Status, the present total anticipated project cost to include all DOE and cost share contributions is $1,029,860. No economic analysis is possible since the preliminary and final designs are yet to be accomplished. These designs await the full development, testing and characterization of the deeper Well No. 2. Therefore, economic parameters such as payback and ROI can not be estimated until approximately Summer 1981.

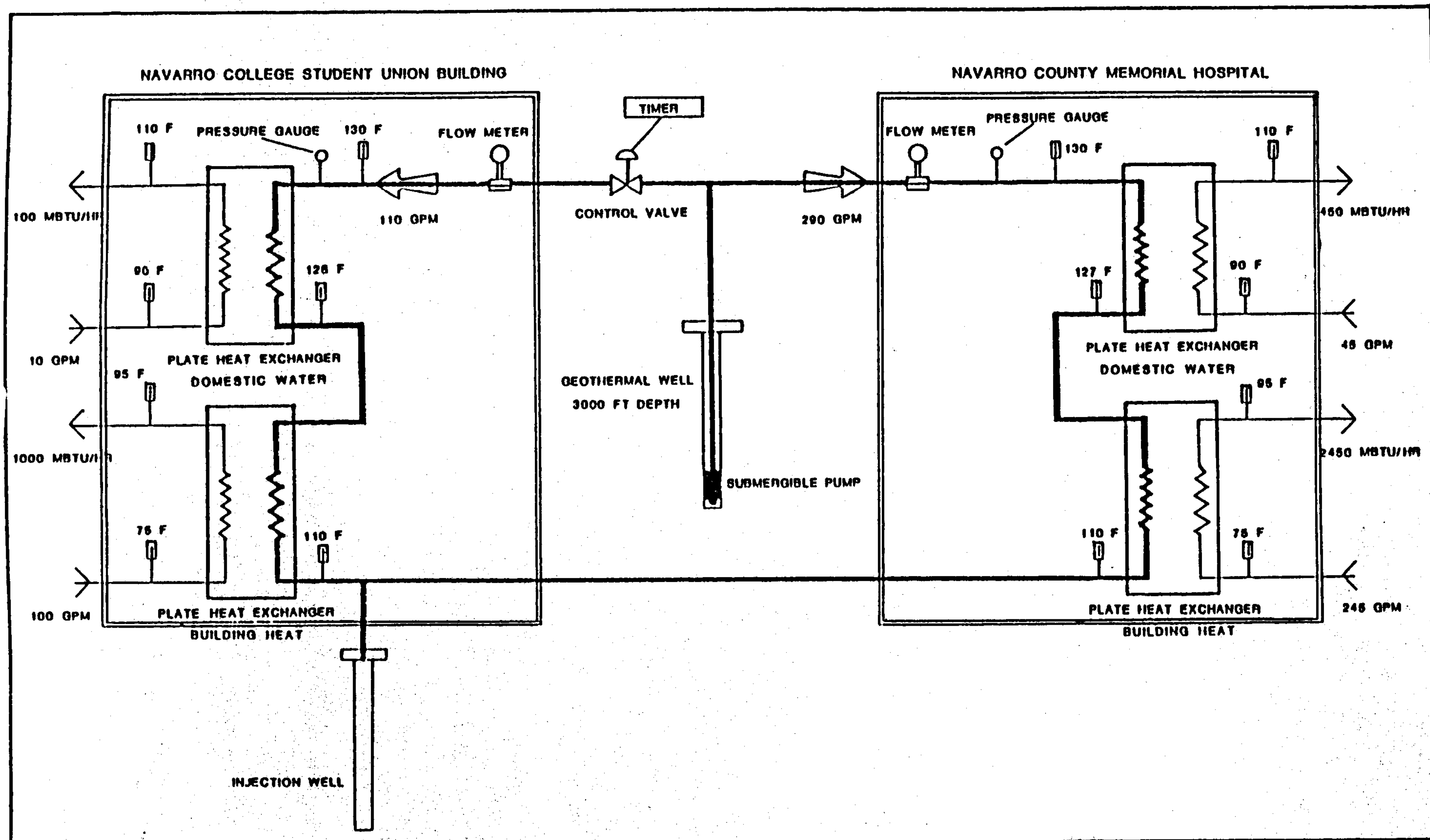

Figure 1. Navarro College-Navarro County Memorial Hospital Geothermal System Conceptual Design

Navarro College
Corsicana, Texas

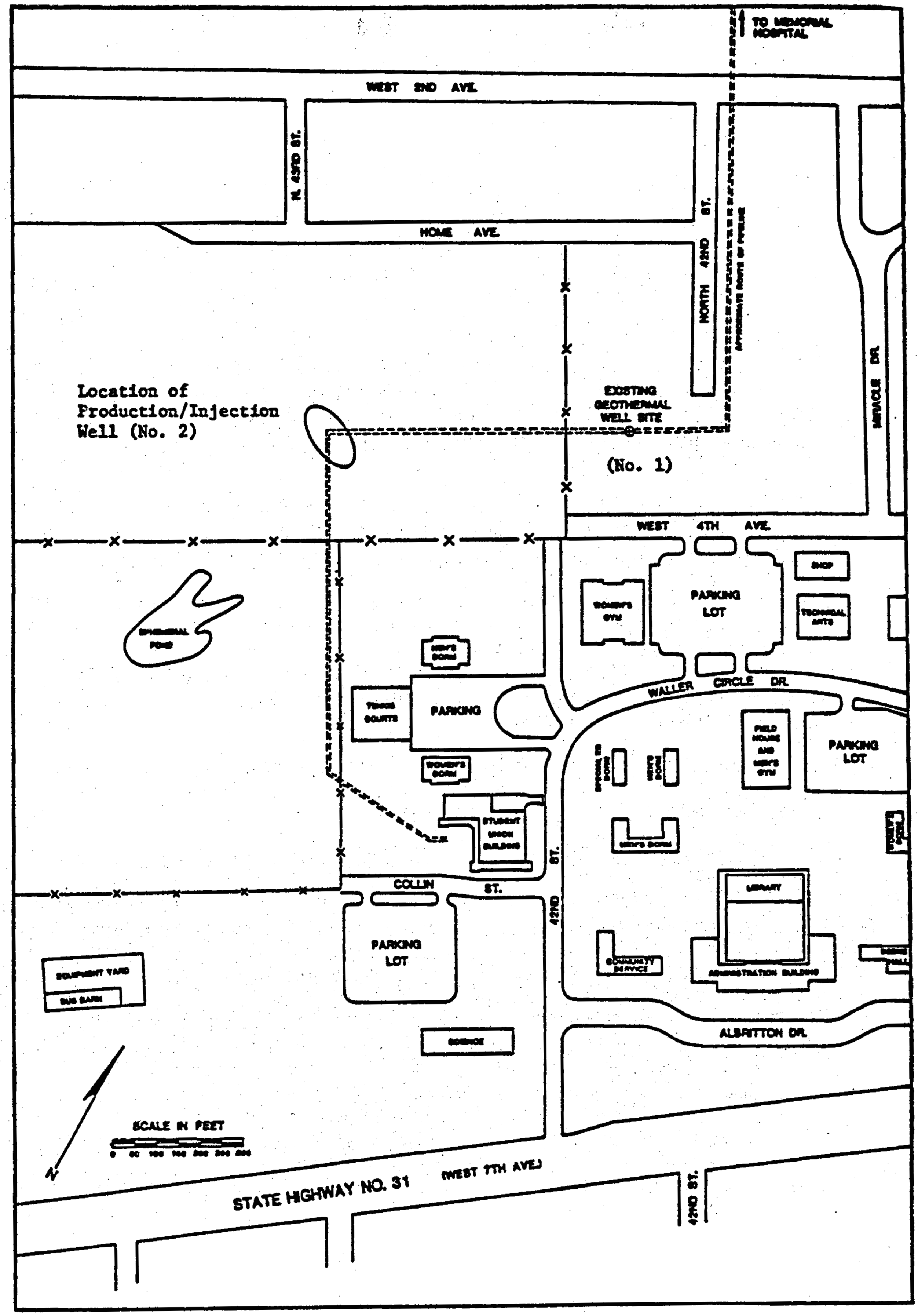

Figure 2. Navarro College Well Locations

II. STATUS

Technical Scope

The following eight tasks represent the proposed scope for the project.

1. Drill a new production well in the Corsicana known geothermal resource area and perform logging and production testing for a final reservoir confirmation.

2. Design and construct a geothermal fluid distribution system between the wellhead and the Navarro College Student Union Building, and the Navarro County Memorial Hospital.

3. Acquire the necessary disposal permits and design and construct an environmentally acceptable geothermal fluid disposal system.

4. Determine performance requirements and design/procure/install and acceptance-test a low temperature geothermal heating system to augment the Navarro College and Navarro County Memorial Hospital space and domestic water heating requirements.

5. Develop an Operations and Maintenance manual for the Navarro College and Navarro County Memorial Hospital geothermal system.

6. Plan and execute a public awareness program for the project.

7. Identify, coordinate and resolve social, legal, environmental and institutional factors which may effect the successful completion of the project.

8. During the initial operational period of the Navarro College and Navarro County Memorial Hospital geothermal system, provide for the attraction of, and information transfer to, potential users of similar systems.

Currently, the major changes in project scope relate to lower temperature and production rates than planned from Well No. 1.

After pump testing Well No. 1, a proposal was submitted to DOE to extend the planned geothermal fluid injection well No. 2 to investigate its potential use as a new production well. It was anticipated that drilling a deeper well to tap the resources of the Travis Peak zone of the Trinity group would provide a hotter fluid for the project and future enhancement of geothermal utilization in Corsicana.

The proposal was approved by DOE and the deeper well was drilled to a total depth of 4760 feet and is currently being tested. Additionally, because of the drawdown levels and required flow rates with attending pump horsepower, some variable flow scheme or tank storage is required to conserve pumping energy costs and enhance the future system economics. Since storage tanks are major sources of unwanted oxygen intrusion and corrosion, a pump variable frequency drive unit will be employed. Through driving at an rpm proportional to the heat demand, electric consumption is frugally used and no oxygen is introduced into the system.

Schedule

The original schedule called for a 40-month project in which drilling, system design, and installation would be accomplished during the first 28 months after which a 12-month operational demonstration would be conducted so that new users could be attracted to the concept of using geothermal fluids in the area.

Due to delays in the drilling of well No. 2 to determine supplementary production fluid flow rate and temperature, a limited amount of work could be performed in other key task areas. The preliminary design of the fluid distribution and building heating systems was begun according to schedule in October and has continued to date but the point has been reached where a production fluid temperature and flow rate is required. Based upon the review of building heat loads and design work conducted so far, fluid of 140°F at a flow rate of 200 gpm will meet the major water and space heating needs planned for the hospital and college in the conceptual design. A fluid temperature of 125°F will provide over 86% of the energy savings that were anticipated in the conceptual design. It is anticipated that necessary design data will be known in the near future from the current well No. 2 flow tests. Once that data is known, it is estimated that the preliminary design can be completed in a few months. The most recent schedule with the expected slippages in areas subsequent to the preliminary design is presented in Figure 3.

NAVARRO COLLEGE AND NAVARRO COUNTY MEMORIAL HOSPITAL GEOTHERMAL PROJECT

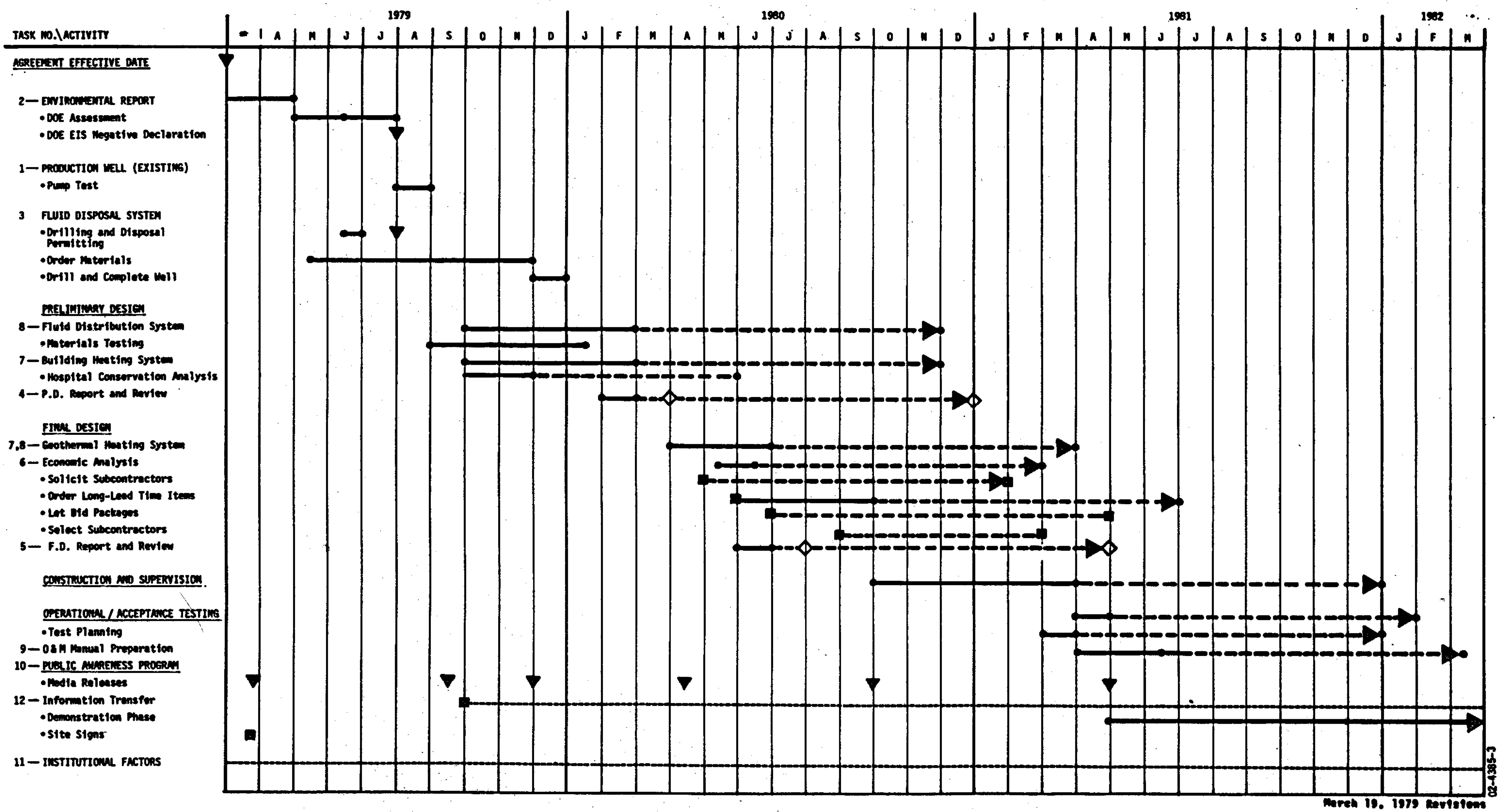

Figure 3. WORK SCHEDULE

Cost

The total estimated cost of the project was originally $866,798 with Navarro College and Navarro County Hospital contributing the equivalent of $184,639 and $13,571 respectively in the production well and in-kind services. An additional $148,062 in funding from DOE for the deeper No. 2 well and approximately $15,000 in steel casing and pipe has been donated by Armco Steel of Houston. These additions have brought the total estimated project cost to $1,029,860.

III. LESSONS LEARNED

The major problem encountered in the program has been the lower than anticipated temperatures and flows from production well No. 1.

Utah State Prison

(Input not received in time for printing)

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PROJECT TITLE: Geothermal Heating of Warm Springs State Hospital (WSSH), Warm Springs, Montana

PRINCIPAL INVESTIGATOR: Karen Barclay, Montana Energy and MHD Research and Development Institute, Inc.

PROJECT DESCRIPTION:

Resource

Warm Springs, Montana is the site of the Montana State Mental Hospital and is located approximately 15 miles south of Deer Lodge in the southwestern part of Montana in Deer Lodge County. The facility is situated in the southern portion of the Deer Lodge Valley on the west side of Interstate 90 and U.S. 10. The valley covers an area of approximately 300 square miles and is roughly 33 miles long (N-S) by 9 miles wide (E-W).

The WSSH production well has been drilled and cased to a depth of 1500 ft. The estimated flow rate is in the order of 300 gpm (pumped) with a temperature of 170°F. Chemical analysis of the water has determined the total dissolved solids content to be approximately 1300 ppm. with a 7.3 pH.

Design

The conceptual system design for the WSSH PON utilizes two central heat exchangers arranged in series with the geothermal water utilized to the maximum by cascading through both exchangers. The hi-temperature heat exchanger will utilize the predicted 170°F geothermal resource to provide water for space heating use (@ 160°F), while the second stage heat exchanger will utilize the exit water from the first (@ 145°F) to provide 140°F water for domestic heating (see Figure). Therefore, each demand can be met by a dedicated heat exchanger providing for continuity of operation when maintenance or repair is required on the other. Combined, the systems will require a flow rate of 300 gpm during the peak of the heating season. During the summer months, when high flow rates are not required, the domestic hot water heating needs may be supplied by the artesian pressure of the well or, if necessary, a small booster pump. It is the intent of the project to maximize the geothermal resource while minimizing the energy consumed yielding a net positive energy balance.

System Economics

Current estimates indicate that the geothermal system would have a payback period of 6-10 years. This is based on the assumption that the system will be utilized 45% of the time and have a system efficiency factor of 90%.

STATUS:

Technical Scope

The Warm Springs State Hospital facility consists of nine patient-occupied buildings and numerous auxiliary structures. The plan for the Demonstration Project is to substitute geothermal energy for natural gas to supply the facility's domestic water heating needs and space heating for the Warren and Food Service Buildings.

The project originally included drilling a 1000 ft. production well, logging and well testing to obtain the maximum heat extraction. The geothermal water is to be pumped through platetype heat exchangers and discharged at approximately 70°F into the Montana Department of Fish, Wildlife, and Park's ponds (adjacent to the hospital) for the creation of waterfowl wetlands.

The original project scope has been followed with the exception of the well drilling. A 1500 ft. production well was completed in December 1979. After analyzing drill cuttings and well logs, the well was acidized using 4000g 15% HCL to stimulate production. Preliminary pump tests after acidizing indicate flow rates from 200-300 gpm and temperatures to 180°F. Further pump testing of the aquifer has been scheduled for April 1980.

Schedule

The DOE-MERDI Cooperative Agreement was signed in February of 1979 and was scheduled for 22 months consisting of the following breakdown by task:

Task I	Environmental Report	February 1979 - April 1979
Task II	Legal Support	March 1979 - January 1980
Task III	Resource Definition	February 1979 - July 1979
Task IV	Well Drilling	October 1979 - December 1979
Task V	Geothermal System Retrofit and Checkout	December 1979 - December 1980

Cost

The total cost of the project is estimated at $663,000 of which DOE will provide $625,000 and the State of Montana $38,000. The amount shared by the State is comprised of a preliminary economic and engineering analysis study, and a geophysical exploration evaluation (both funded by the Department of Natural Resources), and in-kind contributions of equipment and hours by the State A&E and the Department of Institutions. In addition to the $38,000, in-kind services have been provided by the State of Montana in the nature of rights-of-way, easements land for wetlands development, and associated labor hours for design and construction.

In the original contract, well drilling was originally projected to cost $209,000; it is now estimated at approximately $300,000. Increased expenses in the remaining tasks of the project are not currently anticipated.

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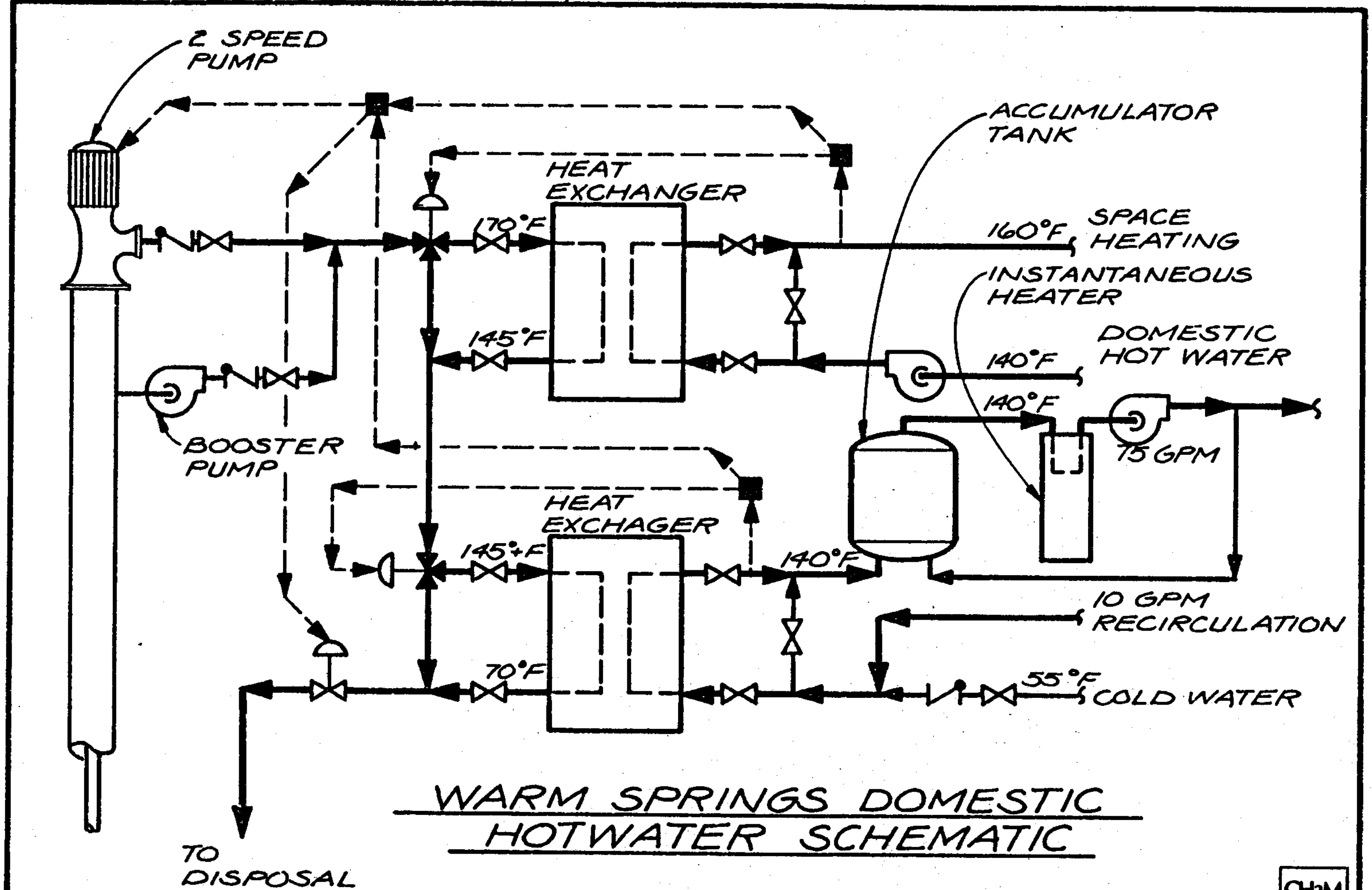


WARM SPRINGS DOMESTIC HOTWATER SCHEMATIC

B13064.A1

CH2M HILL

228

Torbett-Hutchings-Smith
Memorial Hospital

322 Coleman Street Telephone: 817-883-3561
Marlin, Texas 76661

. D. NORRIS, JR.
ADMINISTRATOR

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR SPACE AND WATER HEATING AT THE TORBETT-HUTCHINGS-SMITH (THS) MEMORIAL HOSPITAL MARLIN, TEXAS

TOTAL CAPABILITY PROJECT TEAM

Prime Contractor:	THS Memorial Hospital, Marlin
Geothermal Consulting Engineers:	Radian Corporation, Austin
Architects:	Spencer Associates, Austin
HVAC Engineers:	Ham-Mer Consulting Engineers, Austin
Drilling and Completion:	Layne Texas Co., Dallas
Disposal Well:	Central Texas Savings & Loan, Marlin
Surface Disposal:	City of Marlin
Community Coordination:	Marlin Chamber of Commerce
Legal:	Welch, Parsons & Stem, Marlin
Accounting:	W. M. Parish & Co., Marlin

I. PROJECT DESCRIPTION

Resource

The Ouachita fold belt underlying much of the Gulf Coastal Plain and West Texas is the source of heat, which is located about 30 miles southeast of Waco, Texas in the project area. The Mexia-Talco fault system, east of Marlin, provides a pathway for the hot water from these deeper rocks into the shallower water producing formations of the Trinity Group. Several wells within the city of Marlin have produced water under artesian flow with temperatures as high as 147°F when first drilled in the 1890's. These wells produce fluid from the shallowest formation (Glen Rose) in this group. The fluid has a high mineral content and these old wells have been used for a variety of purposes through the years, such as hot mineral baths and mineral manufacturing. One of the deeper water producing formations within the Trinity Group is the Travis Peak Formation and will be used to supply geothermal fluid for the project. This formation contains fluid with higher temperatures and lower mineral content than fluid from the older wells in the area. The top of this formation is at a depth of about 3400 feet in the Marlin area and is usually referred to as the "basal Trinity sands". The production well for the program was completed at a total depth of 3885 feet. The well produces approximately 75 gallons per minute (gpm) of fluid at 140°F by artesian flow from a production interval of 3613 to 3883 feet through a mill slot screen. Production tests performed on the well using a downhole production pump obtained flow rates of 307 gpm of 153°F. A summary of analyses of the fluid is presented in Table 1. The summary indicates that the fluid contains approximately 4000 mg/l of total dissolved solids (TDS) most of which are sulfates. The total suspended solids concentration is low (approximately 16 mg/l). Hydrogen sulfide, which is only vaguely detectable in the fluid by smell, is also present at low concentrations (approximately 0.1 mg/l).

Design

The program is the first of its kind in Texas which will use Marlin's geothermal water as a source of energy for space and water heating in the hospital. The preliminary design for the retrofit system provides supplementary water and space heating for the major loads in the existing heating system. The geothermal retrofit will provide a significant supplement to the existing heating system without compromising its reliability or integrity. The preliminary design strategy is illustrated in Figure 1. The overall geothermal energy distribution system is divided in four subsystems as follows:

- geothermal fluid production,
- domestic water heating,
- secondary air heating for individual room or zone comfort, and

THS Hospital
Marlin, Texas

TABLE 1. AVERAGE THS FLUID CHEMISTRY

PARAMETER	CONCENTRATION
pH	7.06
Conductivity	4270 µmho-cm
Total Alpha Activity	1.5 pCi/l
	mg/l
Total Dissolved Solids (TDS)	3933
Ammonium (NH_4^+)	1.2
Barium (Ba)	0.055
Bicarbonate (HCO_3^-)	171
Boron (B)	1.5
Calcium (Ca)	299
Carbonate (CO_3^{-2})	0
Chloride (Cl^-)	93
Dissolved Oxygen (D.O.)	0.000
Fluoride (F^-)	1.42
Hydrogen Sulfide (H_2S)	0.13
Iron (Total) (Fe)	3.4
Lithium (Li)	0.53
Magnesium (Mg)	40
Manganese (Mn)	0.23
Nitrate (NO_3^-)	0.3
Potassium (K)	12.2
Silica (SiO_2)	37
Sodium (Na)	901
Strontium (Sr)	7.1
Sulfate (SO_4^{-2})	2343
Zinc (Zn)	0.05

ELEMENTS BELOW DETECTION LIMITS IN THS FLUID

- Aluminum (Al)
- Antimony (Sb)
- Arsenic (As)
- Beryllium (Be)
- Cadmium (Cd)
- Chromium (Cr)
- Cobalt (Co)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Molybdenum (Mo)
- Nickel (Ni)
- Phosphorus (P)
- Selenium (Se)
- Silver (Ag)
- Thallium (Tl)
- Thorium (Th)
- Tin (Sn)
- Titanium (Ti)
- Uranium (U)
- Zirconium (Zr)

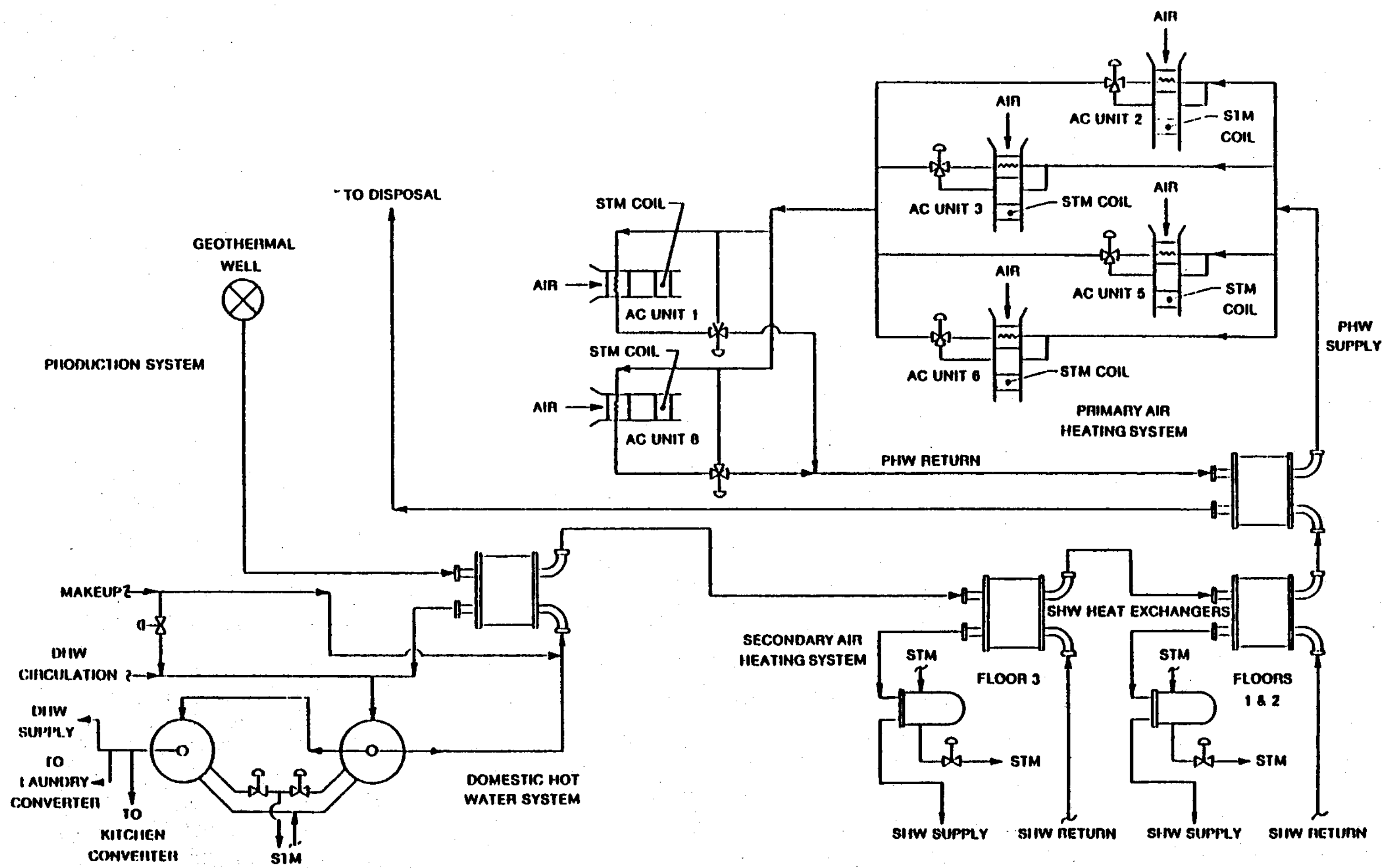


Figure 1. OVERVIEW SCHEMATIC OF GEOTHERMAL HEATING SYSTEM.

primary air heating for patient rooms, nursing stations, perating rooms, hallways, and other areas.

Geothermal energy will be supplied to these subsystems using a cascaded plate heat exchanger arrangement which will supply a substantial amount of the existing heat demand with a minimal geothermal fluid flow rate. The preliminary design resembles the existing heating system except that geothermal fluid will be used instead of steam generated by natural gas-fired boilers. The existing steam system will be used as a backup for the geothermal system.

The tentative locations and piping routes for the geothermal system retrofit are presented in Figure 2. The plate heat exchangers, pumps, and other equipment will be located in a new mechanical room and its adjacent existing storage room. The domestic hot water supply and return line will be buried beneath the paved driveway. Supply and return lines for the two-pipe and three-pipe secondary hot water circuits and for the primary hot water circuit will be routed over the second floor roof up to the penthouse mechanical room. Primary hot water lines for AC Units 1 and for the outside air intake of AC Unit 8 will be routed from the second floor roof down to the first floor roof. The disposal line for the spent geothermal fluid will be buried along the edge of the parking lot and will be discharged into the city storm drainage system.

These locations and routes have the advantage of producing minimal disruption of energency room access during system installation, providing low construction and installation costs, maintaining all new equipment and piping outside the hospital proper, and enabling easy access to piping for maintenance and future geothermal system expansion.

Among the unique features resulting from the use of geothermal at the Hospital are some of the applications of newer designs for heat exchangers and production well pump control systems. Use of thin plate heat exchangers which can easily be assembled and disassembled for inspection, cleaning, and plate replacement will reduce operating problems and major maintenance work in the geothermal side of the system.

Another novel feature to be incorporated on the production system is a variable frequency drive unit to control pump speed in order to match fluid production with heating demand.

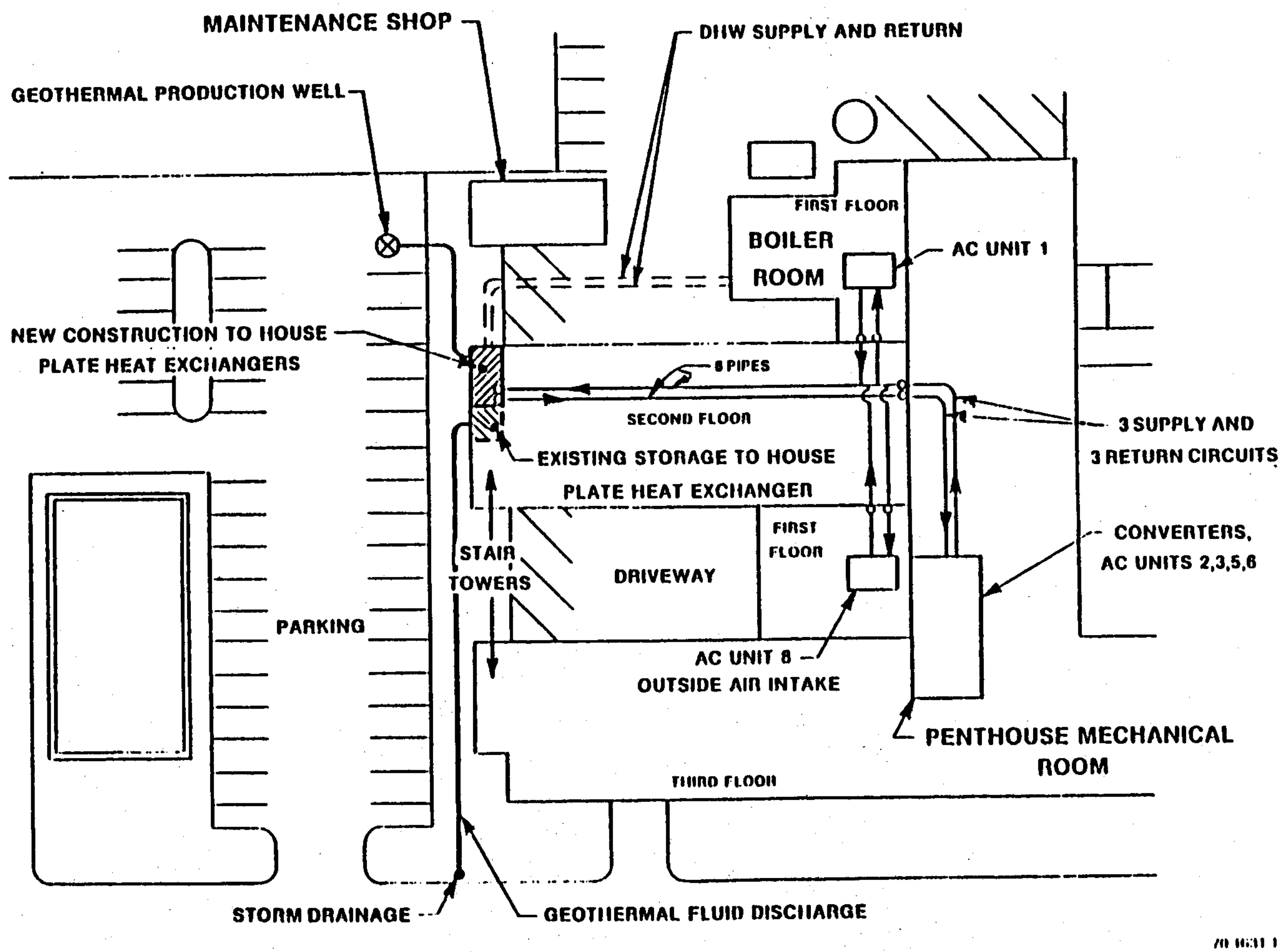


Figure 2. TENTATIVE COMPONENT LOCATIONS AND PIPING ROUTES

System Economics

The geothermal system will supply 81-95 percent of the total average annual heating demand for the affected subsystems at the hospital. Table 2 presents estimates of the contributions of the geothermal system to the existing domestic hot water, secondary air heating, and primary air heating systems. Approximately 9,500 MCF (1,640 bbl of oil equivalent) of natural gas will be saved annually by the direct utilization of geothermal energy.

TABLE 2. ESTIMATES OF GEOTHERMAL CONTRIBUTIONS TO EXISTING HEATING SYSTEM

Subsystem	Contribution Toward Addressed Demand (%)		Contribution Toward Total Demand (%)	
	At Design Conditions	For Annual Average	At Design Conditions	For Annual Average
Domestic Hot Water (DHW)[1]	93	98	92	95
Secondary Air Heating (Secondary Hot Water)[2]	76	91	75	90
Primary Air Heating (Primary Hot Water)[3]	64	86	60	81

[1] Addressed demand contribution based on low temperature hot water generator load. Total demand contribution includes high temperature laundry and kitchen converters Load. Sterilizers load not included.

[2] Addressed demand contribution based on SHW circuits load. Total demand contribution includes load of electric duct heaters.

[3] Addressed demand contribution based on load of Units 1, 2, 3, 5, 6 and 8. Total demand includes load of AC Unit 7.

As indicated later in Section II, Status, the estimated total project cost is $562,000 including all DOE, State of Texas, and in-kind services. Because the system economics cannot be estimated until the final design is accomplished and the corresponding construction cost estimates are made, important economic factors such as payback and ROI can not be determined until later summer 1980.

Since the well was designed and completed to produce about twice the peak flow rate required by the hospital, it is probable that revenue can be obtained by the sale of the excess Btu's.

II. STATUS

Technical Scope

The following list of eight tasks represents the originally proposed scope of the project.

1. Drill a new production well in the Marlin known geothermal resource area and perform logging and production testing for a final reservoir confirmation.

2. Design and construct a geothermal fluid distribution system between the wellhead and the Torbett-Hutchings-Smith Memorial Hospital.

3. Acquire the necessary disposal permits and design and construct an environmentally acceptable geothermal fluid disposal system.

4. Determine performance requirements and design/procure/install and acceptance-test a low temperature geothermal heating system to augment the Torbett-Hutchings-Smith Memorial Hospital space and domestic water heating requirements.

5. Develop an Operations and Maintenance manual for the Torbett-Hutchings-Smith Memorial Hospital geothermal system.

6. Plan and execute a public awareness program for the project.

7. Identify, coordinate and resolve social, legal, environmental and institutional factors which may affect the successful completion of the project.

8. During the initial operational period of the Torbett-Hutchings-Smith Memorial Hospital geothermal system, provide for the attraction of, and information transfer to, potential users of similar systems.

The current scope of the project is very similar to the original scope. However, some individual areas have changed somewhat since the program began. One of the most important changes related to the determination that the space heating load provided by the hot water system was not as great as originally anticipated and that the largest space heating load was to pre-heat fresh (air prior to distribution in the hospital) using steam. Therefore, supplementing the primary air preheating system with geothermal heat was included in the preliminary design to make a substantial contribution in reducing the heat load of the existing system and to maximize the geothermal heating load at the hospital.

Other changes in the technical details of the project include:

- Deepening of the production well by 485 feet during drilling (3885' T.D.)
- Use of a larger diameter long string casing for increased production.
- Inclusion of a materials test section in the system.
- Inclusion of polymer concrete pipe test sections.
- Use of a well production pump equipped with a variable-frequency-drive unit.
- Building an annex room to house the heat exchangers outside of principal hospital areas.
- Investigation of other heating loads for geothermal conversion.
- Support of an application for surface disposal to the Texas Railroad Commission.

Schedule

The original schedule for the proposed 36-month project (5/15/78 - 4/30/81) called for completion of drilling, system design and installation during the first 24 months followed by a 12-month operational demonstration period.

The current estimated schedule to complete the program is shown in Figure 3 based upon the additional revisions. The operational demonstration is now expected to be completed by 30 April 1982.

At this time the well has been successfully completed and production tests indicate that the well will supply substantially more than the heat load required for space heating and water heating at the hospital. Following well production testing, an injection test was conducted at the production well

T-H-S MEMORIAL HOSPITAL GEOTHERMAL PROJECT

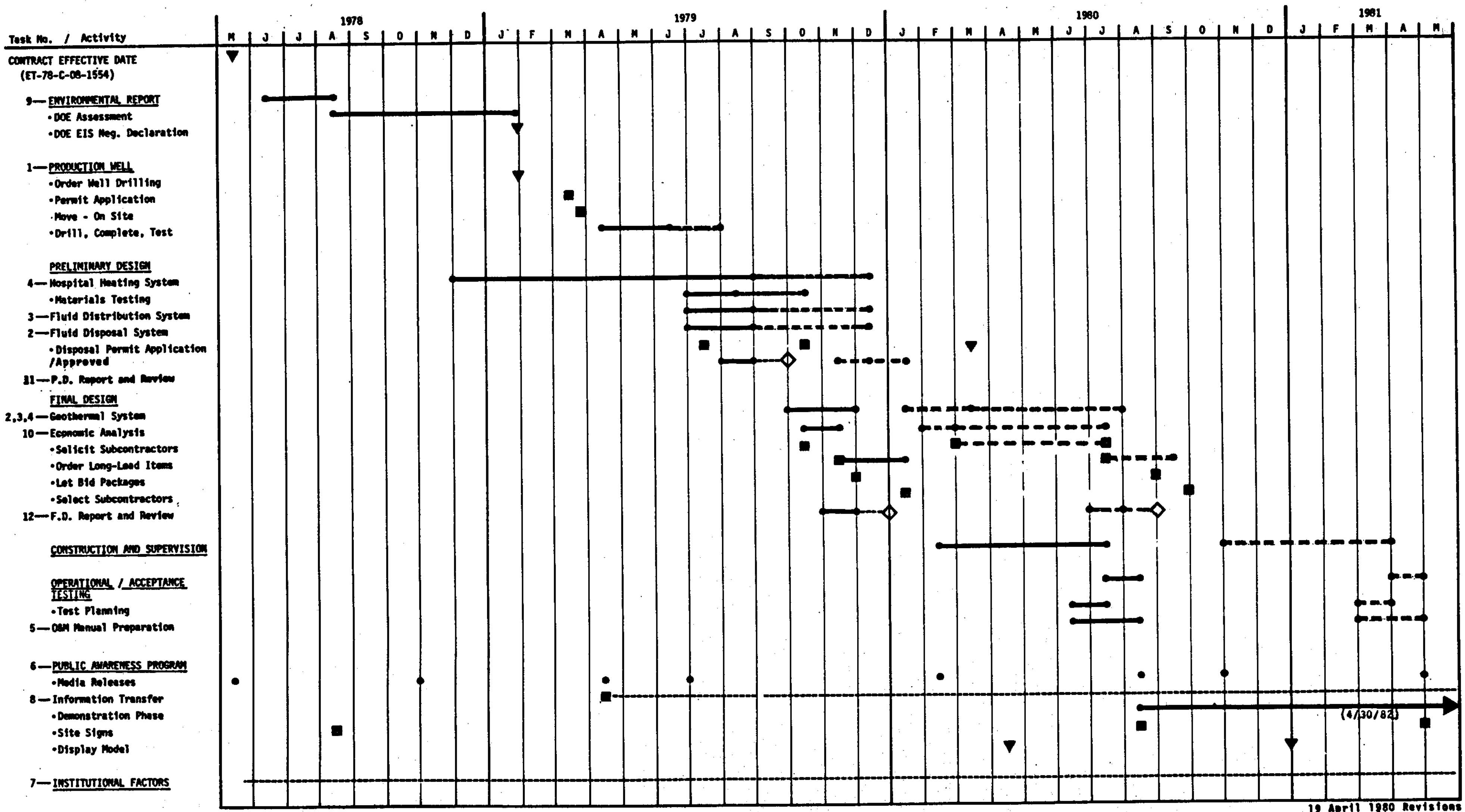


Figure 3. WORK SCHEDULE

and the existing Central Texas Savings and Loan (CTS&L) well which was originally proposed as an injection well for disposal of the geothermal fluid. Test results indicated that the proposed injection well would not be suitable for disposing of the fluid. A request was submitted to the Texas Railroad Commission (TRC) requesting permission for off-lease discharge of the geothermal fluid. After a public hearing and further investigation by State agencies, the TRC approved the disposal permit application on March 17, 1980.

The Preliminary Design Report has been completed and presented to DOE and all interested State agencies. Final design is expected to be completed this summer after investigation of questions posed during the preliminary design review meeting.

The original schedule has slipped due to a number of reasons.

- Additional time required by DOE for the environmental assessment of the project.
- Drilling rig scheduling delays.
- Drilling time required.
- Additional time required due to increased efforts on the preliminary design.
- Regulatory delays for hearings and investigations concerning an acceptable disposal scheme.
- Additional time anticipated to reach a satisfactory final design.

Anticipated future schedule slippages are shown in Figure 3. These result primarily from the previous schedule variances listed above.

Cost

The estimated total cost of the program was originally $657,000. The Federal funding portion remains at $436,800. Local service and state contributions originally totaled $220,200. Since the beginning of the project an additional $5,000 has been contributed by the Texas Energy and Resources Advisory Council. The original CTS&L $100,000 contribution in the form of a disposal well is not applicable now since such disposal is not feasible.

The estimated total cost of the program was originally $657,000. The Federal funding portion remains at $436,800. Local service and state contributions originally totaled $220,200. Since the beginning of the project an additional $5,000 has been contributed by the Texas Energy and Resources Advisory Council. The original $100,000 contribution in the form of a disposal well is not applicable now since such disposal is not feasible.

Such changes yield a total project cost of $562,000 as discussed previously. Contributions from the participating organizations are presented in Table 3.

Currently the total project cost is estimated to exceed the planned $562,000 due to the following:

- Underestimated in-kind services
- Additional cost of drilling the well
- Additional efforts in answering questions concerning the environmental report.
- Additional preliminary design efforts.
- Additional efforts for electrochemical testing of candidate system materials.
- Additional efforts to obtain State approval of the surface disposal plan.
- Unplanned DOE Direct Utilization meetings.

Additional costs will primarily involve inflation and system construction. These include a building annex for the heat exchangers and associated equipment, a well pump and variable-frequency-drive unit, and any costs for larger heat exchangers. Additional costs may also be incurred through the work on the final system design and management of the construction of the system.

TABLE 3. CONTRIBUTORS TO THE MARLIN TORBETT-HUTCHINGS-SMITH MEMORIAL HOSPITAL GEOTHERMAL PROJECT

Contributors		Amount
U.S. Department of Energy		$ 436,800
Texas Energy & Natural Resources Advisory Council		80,000
T-H-S Memorial Hospital		33,600
City of Marlin		11,600
	Total:	$562,000

III. LESSONS LEARNED

The major problems encountered thus far in the program was the inability to use the existing well for disposal of the geothermal fluid as originally proposed. As a result, several alternate disposal options were investigated. The options are listed below in order of preference due to impacts of either increased costs of implementation or increased commitment of public services and/or resources.

1. Surface disposal of geothermal fluid directly to the Brazos River via city storm sewer, City Park Lake, Bean Branch, and McCollough Slough.

2. Surface disposal of treated geothermal fluid via pipeline to City of Marlin entrapment pond for use as possible additional drinking water.

3. Surface disposal of geothermal fluid via pipeline to city entrapment pond (only if fluid quality does not seriously affect drinking water supply).

4. Surface disposal of geothermal fluid to Brazos River via sanitary sewer, Marlin sewage treatment plant, and connecting surface watercourses.

5. Subsurface disposal (reinjection) via a reworked well or a new well.

The cost associated with implementing the first option are minimal because only minor modifications would be required to connect the system to the storm sewer. However, the environmental aspects were, naturally, of concern and a discharge permit was required from the TRC before this option could be implemented. The surface disposal option was analyzed for possible environmental impact associated with releasing geothermal fluids to the Marlin storm sewer system. This technique will introduce the fluids into City Park Lake for dilution and Bean Branch and McCollough Slough before discharging to the Brazos River about four miles away. The effects of the chemical composition of the fluids on the Brazos and chemical and thermal impacts on City Park Lake were evaluated. Results of the preliminary environmental analyses indicate that no significant environmental impacts on the pond's ecosystem will result from surface disposal of the fluid. These results were presented to the TRC during a hearing to obtain a permit for the disposal. No conflicting or opposing evidence or arguments were presented. Approval of the permit application from the TRC has been obtained. This State permitting situation will now be incorporated by DOE into their environmental assessment. The DOE environmental organization is expected to issue their EIS negative declaration on the total project soon.

Geothermal Direct Heat Application

St. Mary's Hospital

Pierre, South Dakota

Principal Investigator

James Russell, Administrator

(605) 224-5941

Project Team

Kirkham, Michael and Associates, Engineers

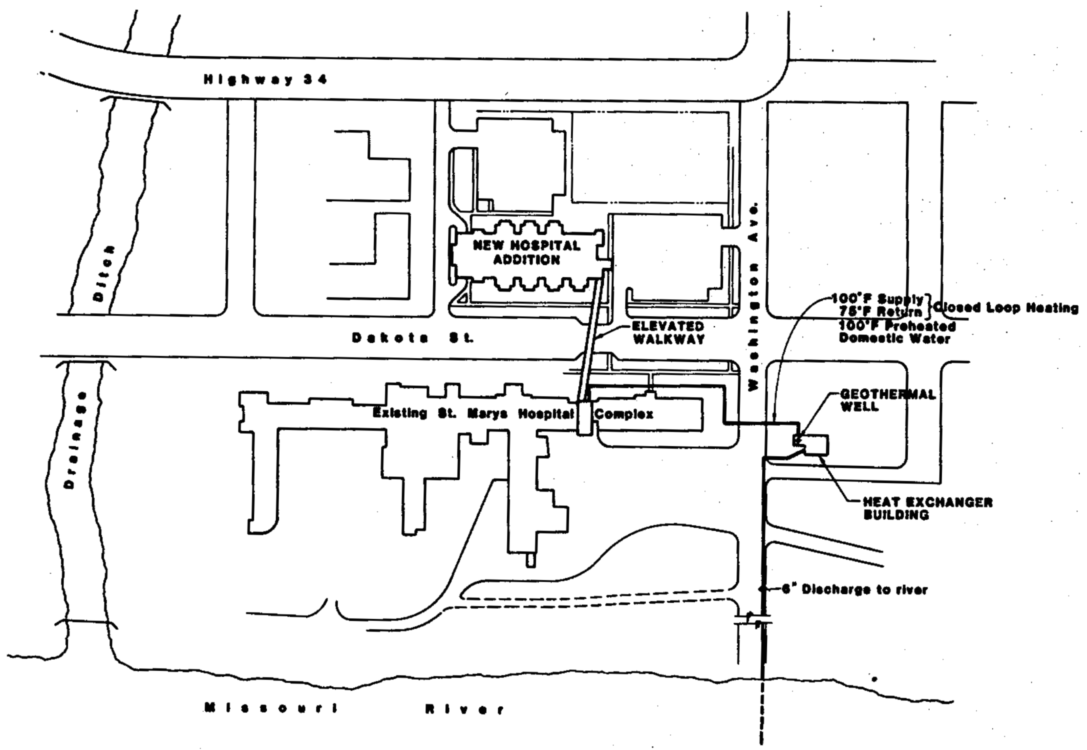
Sherwin Artus, Reservoir Consultant

Dr. J.P. Gries, Geologist

I. PROJECT DESCRIPTION

Resource

This project is located in central South Dakota within the City of Pierre. The Hospital served by the Geothermal well is located on the south side of Pierre approximately 1,000 feet north of the Missouri River which flows around the south edge of the City. The Geothermal energy will be utilized in an 83,000 sq. ft. existing hospital and also in a 65,000 sq. ft. hospital addition which is presently under construction.



St. Mary's Hospital Pierre, South Dakota

The well is located on hospital property in a vacant lot across the street east from the hospital. The well is drilled to a depth of 2,174 feet into the Madison aquifer.

The temperature of the water out of the well is 106° F. The well flow is artesian and flows at a rate of 375 gallons per minute with a residual pressure of 27 psig at the well head. The pressure at the well head with zero flow obtains a maximum of 480 psig.

The water from the well has a total dissolved solids of 2,084 ppm and a hydrogen sulfide content of 0.7 ppm. Complete water analysis as follows:

TABLE I: WATER ANALYSIS FOR ST. MARY'S WELL

Species	PPM	Species	PPM	Species	PPM
(TDS)*	2084	Ca	402	Pb	0.8
HCO_3^-	124	Mg	86	Zn	0.02
Cl	75	Fe	0.3	Cd	0.05
SO_4	1445	Mn	0.25	Hg	0.005
SiO_2	27	B	1.63	HS^-	0.7
Na	50	Cu	0.1	O	1.0
K	21	AG	0.25		

*Total Dissolved Solids

pH = 6.80

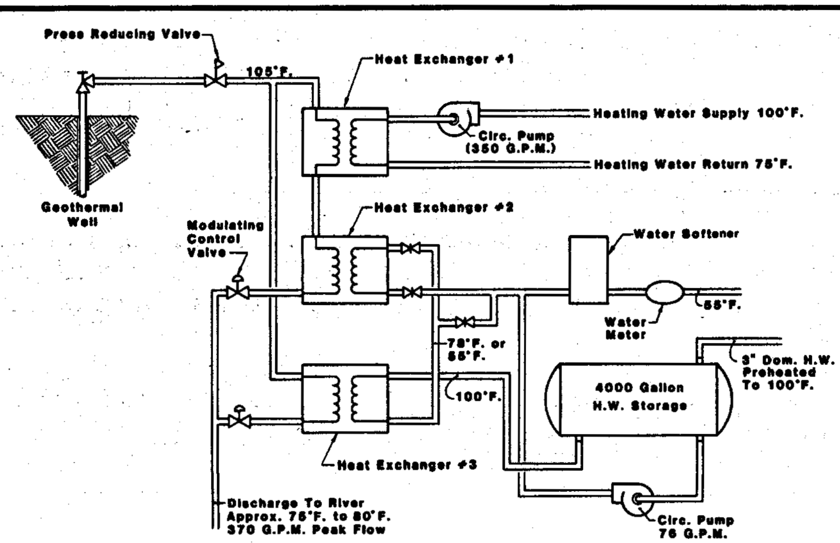
T = 106°F

Design

The heat is extracted from the Geothermal water by three heat exchangers located inside a small building at the well site.

The heat used from Heat Exchanger #1 is by a closed loop system circulated by a centrifugal pump which delivers 100° F. to the building heating systems.

The domestic water, which is preheated by Heat Exchangers 1 and 2, is stored in an insulated 4,000 gallon tank located within the heat exchanger building and made available for use upon demand.



WELL HOUSE AND EXCHANGER BUILDING SCHEMATIC

The well water discharged from the heat exchangers is directed through a 6 in. poly vinyl chloride pipe approximately 1,100 ft. south to the Missouri River. The water will be dispersed through 40 ft. of perforated pipe which extends from a distance of 150 ft. to 190 ft. into the river.

The heat exchangers are in accordance with the following design conditions:

No.	Function	Fluid	Flow gpm	Ent °F	Leav °F
1.	Building Heat	Geothermal	= 350	105	80
		Closed Loop Heating Water	= 350	75	100
2.	Preheat Domestic hot water utilizing thermal discharge from Exchanger #1	Geothermal	= 350	80	75
		Domestic Water	= 76	55	78
3.	Preheat Dom HW (boost from #2 and full preheat when #1 is unloaded)	Geothermal	= 97	105	70
		Domestic Water	= 76	55	100

A corrosion and water quality report indicated that Type 316 stainless steel be the material used for the thin wall plate fin type heat exchangers.

Underground Distribution

The underground closed loop heating water supply and return and the preheated domestic hot water piping from the exchanger building to the hospital facilities is a preinsulated piping system. This piping system consists of a filament wound fiberglas carrier pipe surrounded by 1½" thick poly urethane insulation and jacketed with a poly vinyl chloride pipe. The calculated heat loss in the approximate 450 ft. of underground supply line indicates an average temperature drop in the 100° F. supply water of less than ½° F.

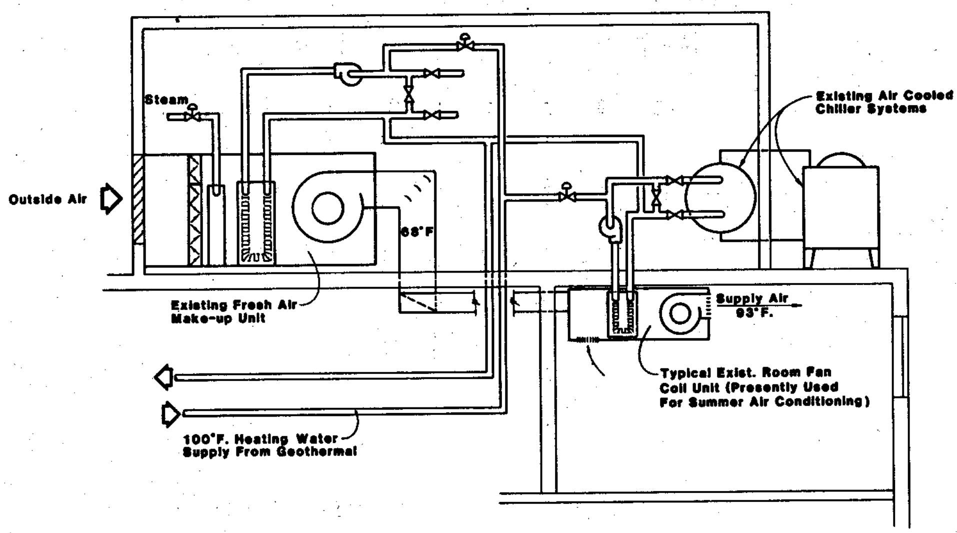
End Use of Heat in Existing Hospital

The 100° F. preheated domestic hot water is connected to the supply to the existing water heater and the existing hospital steam system provides further heating as required.

The closed loop heating water serves two existing systems:

1. Heating of building makeup air for ventilation.

2. Space heating in existing room fan coil units.



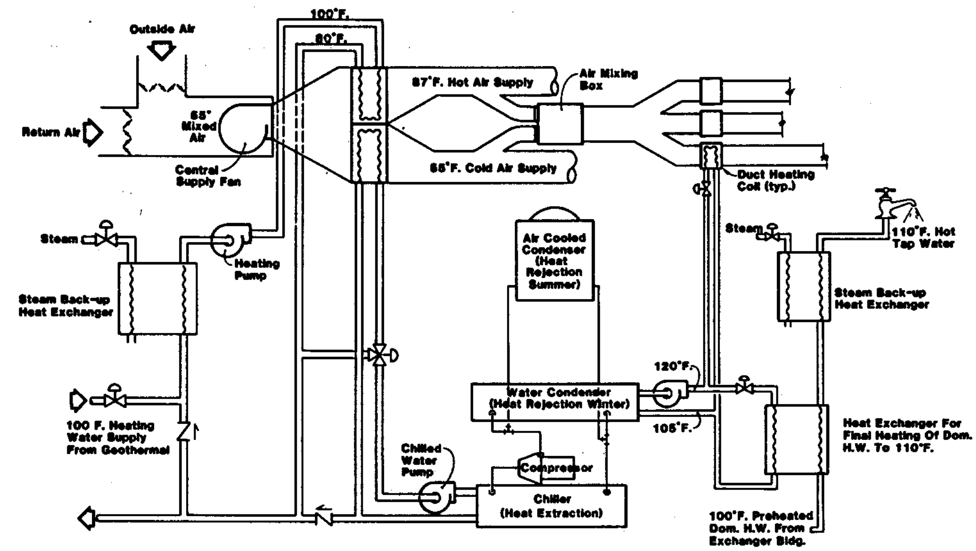
EXISTING HOSPITAL DIRECT HEAT APPLICATIONS

The existing makeup air handling of 15, 650 cfm capacity is located in a penthouse above the hospital. A six row chilled water coil existing in this unit will be supplied with the 100° F. water from the closed loop. Under a peak heating condition of heating this 15,650 cfm air from -30° F. to 68° F., 90 GPM of 100° water entering the coil would leave the coil at 63.2° F.

The present heating system in the existing hospital is basically steam perimeter radiation. A fan coil system has been added to provide air conditioning. Chilled water at the average temperature of 50° F. is circulated in the summer to provide approximately 57° to 59° supply air off the coils. In the winter time, 100° F. water will be provided to these coils to produce 90° F. heated air which is adequate to heat the spaces served during outside temperatures of approximately 2° F. and above.

New Building Addition Application

155 gpm of 100° F. water from Heat Exchanger #1, representing 2,000,000 BTUH, will be available for use in the new hospital addition that is presently under construction. The new heating system is designed to utilize the Geothermal heat source.



NEW BUILDING HEATING SYSTEM SCHEMATIC

The Geothermal energy is utilized directly in the hot deck coil of the main building air handling units. As the outside temperature drops and the demand for heat increases, further energy is extracted from the Geothermal by directing a portion of the approximate 80° F. return water from the hot deck into the chiller. Heat is then taken from the condenser or hot side of the chiller in the form of 120° F warm water for use in individual space heating coils. This condenser water is also utilized to add heat to the 100° F. preheated domestic hot water to raise it to a final use temperature of 110° F.

Instrumentation

Meters and recording equipment are being furnished to provide visual indication and seven day recording chart for the following:

1. Well head pressure (500 psig max. to 10 psig min.).

2. Well supply temperature 106° F ±10° F.

3. Well discharge after heat exchangers (60° F to 106° F).

4. Well flow rate (0-400 gpm range).

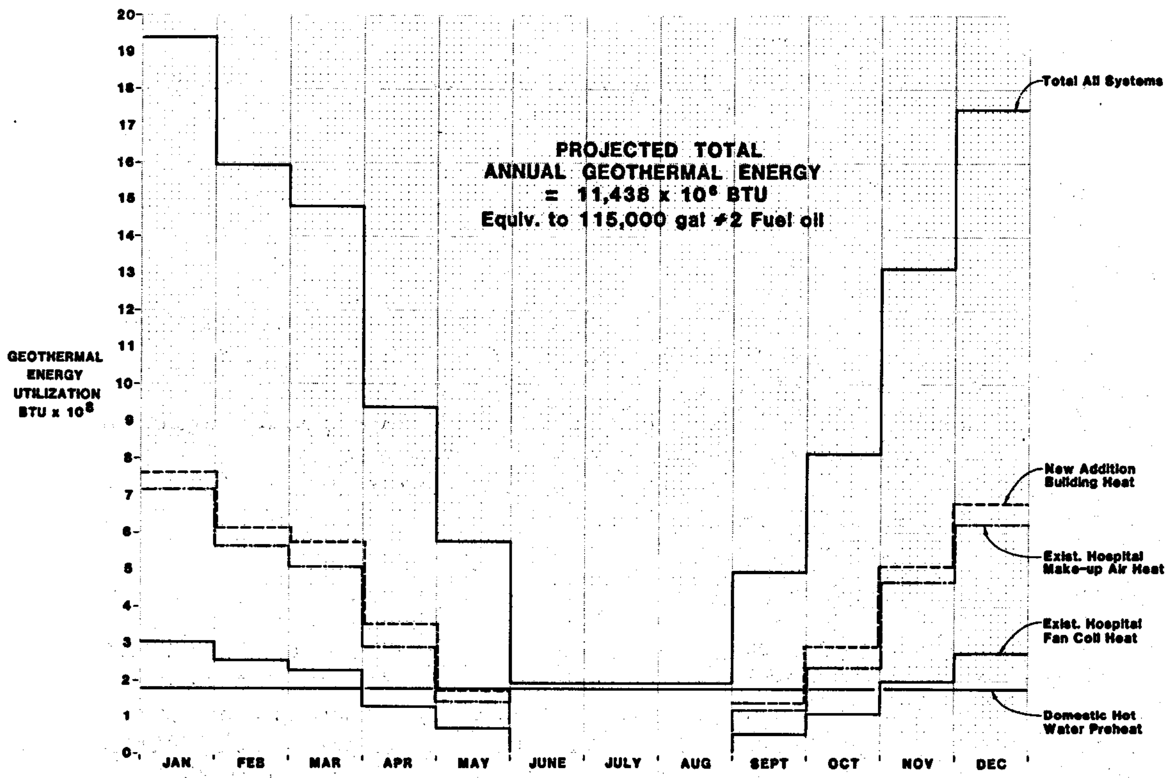
5. Closed loop heating water supply temperature.

BTU computer to indicate BTU rate and BTU totalizer for both the total Geothermal flow and for the closed loop heating water system.

By subtracting the BTU's used in the closed loop from the total used, the amount utilized for domestic hot water heat is obtained.

System Economics

The projected month by month Geothermal energy utilization for the building heating system's calculation are plotted on the following graph.



Geothermal Energy Utilized

Fuel oil is the present source of heat energy for St. Mary's Hospital. Energy from the Geothermal source is expected to reduce the hospital's future demand for fuel oil by 115,000 gallons per year.

Based on a simple payback formula of initial cost divided by annual cost savings, the project economics are as follows:

ECONOMIC DATA

• TOTAL PROJECT COST		: $718,000
• ANNUAL FUEL OIL SAVINGS	: 115,000 Gal.	
	X.95/Gal.	
TOTAL	: $109,250	
• ANNUAL OPERATION & MAINTENANCE COSTS		
Added Pumping Energy Cost	: $840	
Annual Maintenance Cost	: 10,000	
Operational Cost	: 20,000	
TOTAL	: $ 30,840	

• OVERALL PROJECT SIMPLE PAYBACK

$$\frac{\$718{,}000 \text{ Total Cost}}{(\$109{,}250 \text{ Annual Fuel Saving} - \$30{,}840 \text{ Oper.\&Maint. Cost})} : 9.15 \text{ YEARS}$$

• PAYBACK TO OWNER
@ 25% SHARE OF TOTAL COST

$$\frac{\$718{,}000 \times .25}{\$109{,}250 - \$30{,}840} : 2.3 \text{ YEARS}$$

The flow demand on the well will vary in direct relation to the system demand for energy from a peak requirement of approximately 360 gpm during the coldest winter month to approximately 96 gpm during the summer for domestic hot water preheating. The calculated total annual well water consumption is 51.1 million gallons.

II. STATUS

The well was completed in April of 1979. The original flow rate was approximately 250 gpm. After further perforations of the well casing and by pumping 8,000 gallons of 20 percent HCL solution into the well, the flow rate was increased to the present level of 375 gpm.

All of the work to complete the application of the Geothermal resource is now under contract and the construction is proceeding.

The exchanger building, which also houses the well, is complete and work is continuing on installation of the heat exchangers and related equipment.

Schedule

Our original schedule was to have the system complete and operational in the late fall of 1979. It appears now that our completion date will be from eight to nine months past our original scheduled completion. Some of the reasons for our schedule slippages are as follows:

1. Difficulty in obtaining qualified well drillers willing to move into the Pierre, South Dakota area.

2. Production problem with the completed well which required additional work effort to increase the well production.

3. Additional testing required to determine the concentration levels of Radium 226.

4. Delay in obtaining and determining the final discharge point and discharge method of the Geothermal wastewater.

Cost

The total project cost of $718,000 represents approximately 150 percent overrun in our original estimated cost of the well ($125,000 original estimate) and approximately 20 percent overrun in the retrofit work.

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR PHILIP SCHOOLS
Location: Philip, South Dakota
Principal Investigator: Charles A. Maxon, Superintendent of Schools
Project Team: Haakon School District 27-1
Hengel, Berg & Associates
Rapid City, South Dakota

Project Resource

The geothermal resource used for this project is the water obtained from the Madison Formation. The Madison Formation underlies much of Western South Dakota. The depth to the top of the Madison Formation varies from 3,000 ft. from the Missouri River to approximately 7,000 ft. in the northwest corner of the state. The Madison Formation is near the surface in the vacinity of the Black Hills in the west central part of the state.

The temperature of the water in the Madison Formation varies from 110 degrees F. in the west to 160 degrees F. in the Philip area. There have been a limited number of wells drilled to the Madison Formation. All of these wells have artesian flow.

As part of this demonstration project, a new well was drilled adjacent to the school buildings in Philip, SD. The well was drilled using conventional drilling techniques.

The first 1,000 ft. of the well has a 15" diameter bore hole with a 10 3/4" #H-40 casing cemented in place. From the 1,000 ft. depth to the 3,850 ft. depth the bore hole diameter was 9 7/8". A 7 5/8" casing was suspended inside the 10 3/4" casing near the bottom of that casing. This lower casing was also cemented in place.

The plans called for a 6 1/4" bore hole for open hole completion of the well, for 300 ft. below the 3725 elevation. From samples of the cuttings it was apparent that limestone of good water bearing porosity was not penetrated until a depth of 3,900 ft. had been reached. Upon recommendation of the geologist, drilling continued through the limestone and dolomite which has a fair porosity until a total depth of 4,266 ft. was reached.

Electronic logging of the hole indicated that there was a zone of intermittent layers of dolomite and shale in the top section of the hole and also a section of red sandstone which could be a source of future problems. To prevent any future problems of sluffing of the sandstones and shales into the open hole, a 5" OD flush joint casing was suspended inside the 7 5/8" casing to a depth of 3,900 ft. The total depth of the well is 4,266 ft.

Flow tests indicate that the well will deliver 300 gallons per minute, at a temperature of 157 degrees F. The well is artesian flow and has a close-in pressure of 128 PSI.

Samples of the water were analyzed at the Engineering and Mining Experiment station at the South Dakota School of Mines and Technology in Rapid City, SD. Their analysis indicates that the water from the Philip School well is similar to the water obtained from the City of Philip well, which is 3 miles northeast of the site. The water contains approximately 1,100 parts per million of total desolved solids. The water also contains approximately 200 parts per million of calcium, 740 parts per million sulfate, and from 12 to 48 parts per million each of chloride, magnesium, sodium, iron, and silica. The pH of the water is approximately 7.7.

Testing by the South Dakota Department of Water Quality and by the EG & G Idaho, Inc. indicates that the water contains approximately 100 picocuries per liter of Radium 226 (Ra-226).

Corrosion Evaluation

After the flow testing was completed a test rack was installed and connected to the well. One test rack had polished sets of coupons. The other test rack contained a stress rack. Both test racks had samples of materials that might possibly be used in the goethermal heating system. The test racks were connected to the well for approximately 45 days. After the 45 days the test racks were removed and delivered to the South Dakota School of Mines and Technology Mining and Experiment Station for analysis. From their analysis it is apparent that this well is similar to the Philip City well. There has been an ongoing material test at the Philip City well. The correlation between the 2 wells indicates that 316 stainless steel is the preferred metal to use in the system wherever metal comes into contact with the well water.

Design

The piping was designed to deliver 250 gallons per minute to a tee outside of the Armory High School Building. At this point 150 gallons per minute will be delivered to the Armory High School and 100 gallons per minute will be piped to the Elementary School Building. The 150 gallons per minute delivered to the Armory High School would be returned in a separate line that will be connected to the return line from the Elementary School Building.

The system is designed so that the water will always enter the building before being put into a return or discharge line. The piping inside the building is designed to permit the water to either flow through a plate-type heat exchanger or be bypassed and returned to the return or discharge line. The piping system is shown in figure 1.

Two plate-type stainless steel heat exchangers for each building will be installed in the Armory High School Building and in the Elementary School Building. One of the exhangers will be used for space heating and the other exchanger will be used for domestic hot water. These buildings are presently heated with a low pressure steam heating system. This existing system will be modified to a hot water system by replacing steam coils with hot water coils in some of the fan coil units, by adding additional fan coil units, new baseboard radiation units, and by using some of the existing baseboard radiation units. Because of the condition of one of the boilers it will be replaced and the other boiler will be retrimmed for a hot water boiler. These boilers will be used as a back-up system to the geothermal system. Figure 2 is a typical schematic piping diagram that shows the inter-connection between the geothermal heating system and the conventional boiler system. Also shown in figure 2 is the typical piping diagram from the boiler room to the heating terminal units.

The Armory High School Building has approximately 30,000 sq. ft. The Elementary School Building, the Vocational Education Building, and 2 small buildings used for music classrooms have approximately 28,000 sq. ft. and will be heated by the heat exchanger in the Elementary School Building boiler room. The geothermal heat will replace the electric heat in the Vocational Education Building and propane space heaters in the two small buildings.

The design flow of 250 gallons per minute will utilize the artesian flow of the well. The well head pressure at 250 gallons per minute will be approximately 40 psi. The design temperature for the entering water temperature is 155 degrees F. Maximum ΔT is 20 degrees F. At maximum requirement for heat in the building the leaving water tempurature will be approximately 130 degrees F.

The discharge line is routed to the Bad River. Along the discharge route are 8 business building that will be connected to the discharge line. These 8 building will utilize the 130 degree F. water for part of their heating requirements. With a temperature drop of approximately 20 degrees F. the geothermal water could provide approximately one half of their annual heating requirements. The piping layout of the discharge line from the school to the discharge point is shown in figure 3.

The flow of the water through the system is controlled at two points. There is a motor operated modulating flow control valve at the well head. This valve is controlled by a proportional temperature controller with an outdoor bulb. There is a second motor operated modulating flow control valve in the firehall, which is at the end of the heating district line. This, also, is controlled by a proportional temperature controller.

The pressure at the well head is regulated by a Clayton pressure reducing valve. This valve will be set to maintain a maximum pressure on the system. A Clayton valve will also be installed in one line at the firehall. This valve is a combination pressure relief, pressure sustaining and back pressure valve.

The modulating flow control valve and the combination pressure relief, pressure sustaining and back pressure valve in the firehall will be used to regulate the flow through the heating district system. Figure 4 shows the well head piping and valve arrangement and figure 5 shows the control and piping schematic at the firehouse.

The owners of these 8 buildings are providing the financing for the return line that is to be installed in the trench with the discharge line.

A discharge permit to discharge the geothermal water into the Bad River would not be granted by the Environmental Protection Agency unless the Radium 226 was removed from the water. Various methods of removing Radium 226 from water were studied. To reduce the Radium 226 level to less than the 5 picocuries per liter permitted, a process using a barium chloride solution was selected. A 10% aqueous solution of barium chloride is injected into the geothermal water. The water then passes through a static mixer and is discharged into a holding pond. To provide flexibility the project was designed with a double cell holding pond. The valving was designed so that each pond could be used individually or they could be used as a single unit. Two chemical mixing tanks with agitators and metering pumps will be provided. When one chemical feed tank is empty the control panel will switch automatically to the other tank. If both tanks are empty a red warning light will be turned on outside of the building. This system was designed for operation with a minimum supervision. The floorplan and piping details are shown in figure 6. The plan view of the ponds is shown in figure 7.

The barium chloride molecules attract the Radium 226 and form a flock which will settle out of the water. After approximately 2 days of retention time the barium sulfate Radium 226 flock will have settled out of the water. A baffled overflow structure will be provided to take water off of the top of the pond and discharge it to the Northfork of the Bad River.

Systems Economics

The heat from the geothermal resource will replace approximately 36,200 gallons (approximately 860 barrels) of fuel oil per year and 107,000 KWH per year for the Haakon School District. The geothermal resource will also replace one half of the fossil fuel used to heat the 8 business buildings in the City of Philip. One half of the fossil fuel amounts to approximately 26,000 gallons (622 barrels) per year. Based on the government projected fuel cost increases in the future, the payback period would be approximately 20 years for the entire project. However, the current fuel oil costs in this area are greater then the projected price. With a 10% rise in fuel cost each year the payback period would be approximately 14 years for the entire project. The payback period for each of the 8 business buildings varies from about 5 years to approximately 17 years, depending on the complexity of the heating system for each of the buildings.

For the first 5 years of the operation of the system, The Philip Geothermal, Inc., the legal entity for the heating district, will reimburse the Haakon School District $2,500 per year as their share of operating and maintenance cost. This fee is subject to renegotiation after 5 years.

The well with casing and valve cost $277,449.00.

The discharge pipe line bid is $249,700.00, the Barium Chloride Treatment plant bid is $116,700. The four stainless steel plate type heat exchangers were purchased on a separate bid for $13,600.00.

The modification and conversion of the heating system bids were $149,802.00 for the Armory High School Building, $108,503.00 for the Elementary School Building, $30,354.00 for the Vocational Education Building, and $13,820.00 for the two small music buildings.

Status

The scope of this demonstation project has been subsantially increased. As originally proposed, the project involved drilling the well for the school, modifying the heating systems in the school buildings and discharging the water into a dam that flows into the Bad River.

Factors that influenced the change in scope of the project include the following:

1. The well produces only 250 gallons per minute vurses the anticipated 425 gallons per minute.
2. The lower volume of water available to the school required the use of a larger ΔT, which in turn provided a lower system side temperature.
3. After the well was completed interest was developed in the business community in Philip to further utilize this resource.
4. To provide additional use of this resource the discharge pipeline route was changed to route it near the business district.
5. Water quality tests indicated that the water had a Radium 226 content above that permitted by EPA for disposal.

The current scope of the project includes drilling the well, utilizing the geothermal resource to heat the school buildings, provide one half of the heat requirement for eight business buildings, and a plant to remove the Radium 226 from the water.

The local grain elevator owned by the Farmers Co-op Association is studying the possibility of constructing a grain alcohol plant. As part of their study they are considering utilizing the geothermal heat for part of their heat requirements. They are also studying the possibility of utilizing part of the geothermal heat for a grain drying operation.

The project will be completed approximately one year behind schedule. The one year slippage is an accumulation of unanticipated delays, caused in part by outside agencies.

The South Dakota Water Rights Commission postponed the issuance of a drilling permit for two and one half months. This in turn delayed the completion of the well plans and specification.

The well driller encountered difficulties while drilling the well. His anticipated twenty days at the site extended into approximately seventy-five days at the site.

To complete the design of the conversion of the heating systems, it was necessary to know the actual capabilities of the resource. The flow test was not completed until the end of March, 1979. With the information from the flow test, the final design proceeded.

The conversion of the existing heating systems in the school buildings will have to be completed during a summer recess. To fit the conversion of the heating system into the school's schedule, this work was then scheduled to be completed during the summer of 1980.

The design of the conversion of the heating system was underway when it was learned that the water contained Radium 226. Design work on the conversion was temperarily halted while the various methods of removing the Radium 226 were investigated. The use of the barium chloride to remove the Radium 226, as a barium sulfate Radium 226 precipitate, was selected as the most economical method to handle the problem.

With the discovery of the Radium 226 in the water, the South Dakota Environmental Protection Agency advised the owner that a discharge permit would be required to discharge the water into the Bad River, after treatment. The discharge permit was applied for in August of 1979. The draft permit was prepared by the South Dakota Envirnomental Protection Agency. Because this is the first permit of this type involving radiological problems, the draft permit had to be reviewed by several people in the Department of Environmental Protection. The final approval of the discharge permit is vested with the Federal Environmental Protection Agency, Region Eight, Denver, Colorado. The Federal Environmental Protection Agency has completed all of the necessary advertising and public hearings for the permit. There were no adverse comments, therefore the permit will be issued in March of 1980.

Accomplishments

Haakon School District 27-1, has obtained a water right to drill the well. The well has been drilled and tested. The well provides a geothermal resource that will provide 300 gallons per minute of 157 degree F. water. To utizlize the well pressure for movement of the water, the system was designed to use 250 gallons per minute.

The design of the heating system conversion has been completed. The design of the discharge pipeline and distribution pipelines for the City heating district has been completed. The plans and specifications for the barium chloride plant, that is to remove the Radium 226, has been completed.

Easements for the route of the discharge pipeline have been obtained from the Division of Highways, South Dakota Transportaion Department, the City of Philip, and private land owners, across who's property the pipeline is to be installed.

An option for the site for the Barium Chloride Treatment Plant has been obtained.

The project was advertised for bids. The bid opening took place on February 27, 1980. The construction phase of the project was divided into two contracts. One contract included all of the modification work inside of the school buildings and the other contract included all of the pipeline construction including valves and fittings that the well had, valves and fittings at the Firehall, the Barium Chloride Treatment Facility, and the pipeline.

Three bids were received on the heating system conversion project and only one bid was received on the pipeline project. All of the bids were referred to the engineer for evaluation. The decision whether to award the contracts or reject the bids will be made on March 21, 1980.

Cost

The cost of the project as originally envisioned was estimated to be $483,470. This estimate was made in November of 1977. After the latest bid opening the cost of all of the large items is now fixed. With all of the changes and additions plus escalation for inflation, the project cost now is anticipated to be $1,144,500. The major items of cost overrun included the well and casing, the discharge pipeline, the heating modifications, and the addition of the Barium Chloride Treatment Plant.

The cost share for the project is still on the same basis of 80 per cent DOE and 20 per cent Haakon School District. The cost of the return line, the service supply and return lines, valves and other related items for the district heating system will be paid 100 per cent by the heating district, Philip Geothermal, Inc.

The size of the overrun can be correlated with the change in scope of the project and the time delays.

Lessons Learned

Technical Problems

If the well was to be redrilled, serious consideration would be given to drilling the open hole section to the same diameter as the section above. Then if an area shale lenses or soft sandstone were encounted the full casing could be extended to cover those points without having to add additional liner hanger and casing. Several thousand dollars could have been saved using this method.

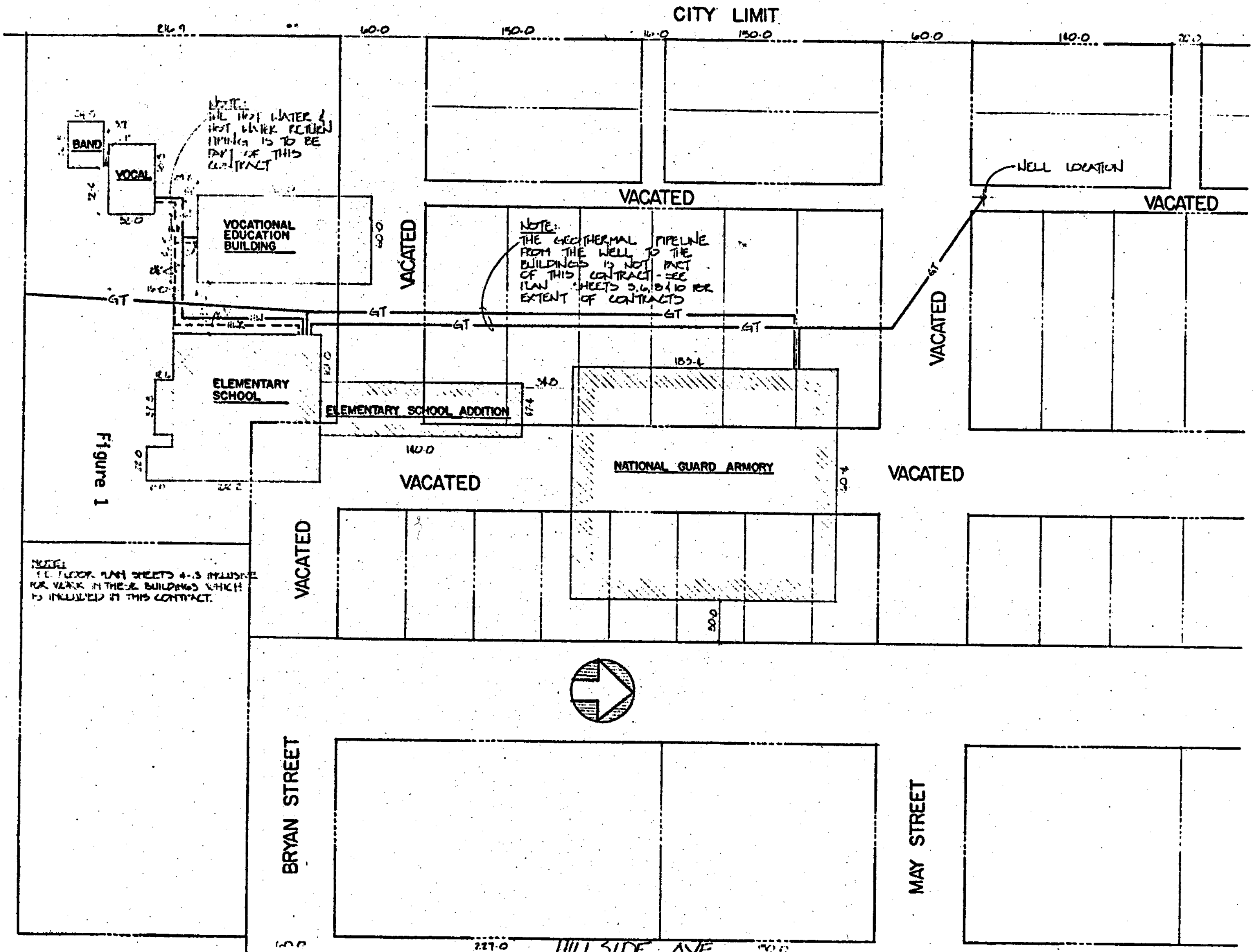
A great deal of time was spent searching for a pipe that would meet the requirments for the project. The water chemistry and temperature required that the pipe be non-corrosive yet capable of operating at pressures of approximately 175 PSI with temperatures of 155 degrees F. Schedule 40 steel was eliminated because the water would severely corrode that type of pipe. PVC and CPVC were eliminated because of the high pressure temperature range. The pipe finally selected for the project was a filament wound epoxy resin pipe manufactured by Ameron Company. Consideration was given to a similar pipe manufactured by A.O. Smith/Inland, however they did not manufacture the fittings using the same process. Their fittings were a molded type, which according to information we received, the molded fitting are more prone to splitting when exposed to conditions similar to those on our project.

The selection of the material used for heat exchangers for this project was critical. Based on the coupon tests, a plate type heat exchanger manufactured from 316 stainless steel was selected for the project.

Environmental

The presence of Radium 226 in the water has created an expensive problem. The removal method selected using barium chloride is a standard method used by uranium milling companies to treat process water.

The removal of the Radium 226 using the barium chloride treatment presents a secondary environmental problem. The precipitate, or sludge accumulation in the bottom of the ponds amounts to approximately 3 cubic yards of wet sludge per year. The Radium 226 would accumulate at the rate of approximately 0.06 curie per year in the bottom of the pond. As long as water remains in the pond so that the radium is unavailable to become airborn, there exists no radiological hazard. However, at some point in time the sludge build-up will have to be disposed of in some manner. Based on the excess volume of the ponds an accumulation of 30 years sludge could be tolerated. After 30 years the sludge could be dried and removed in accordance with the regulations for handling radiological waste. Or the sludge could be mixed with cement, allowed to harden and become the bottom of a new pond. The new pond being created by raising the dikes of the existing pond. These options will be submitted to the South Dakota Department of Environmental Protection for their consideration and acceptance.



CITY LIMIT
BAND
VOCAL
VOCATIONAL EDUCATION BUILDING
ELEMENTARY SCHOOL
ELEMENTARY SCHOOL ADDITION
NATIONAL GUARD ARMORY
VACATED
VACATED
VACATED
VACATED
VACATED
VACATED
VACATED
WELL LOCATION
GT
NOTE: THE GEOTHERMAL PIPELINE FROM THE WELL TO THE BUILDINGS IS NOT PART OF THIS CONTRACT - SEE PLAN SHEETS 5,6,8 & 10 FOR EXTENT OF CONTRACTS
BRYAN STREET
MAY STREET
HILLSIDE AVE

Figure 1

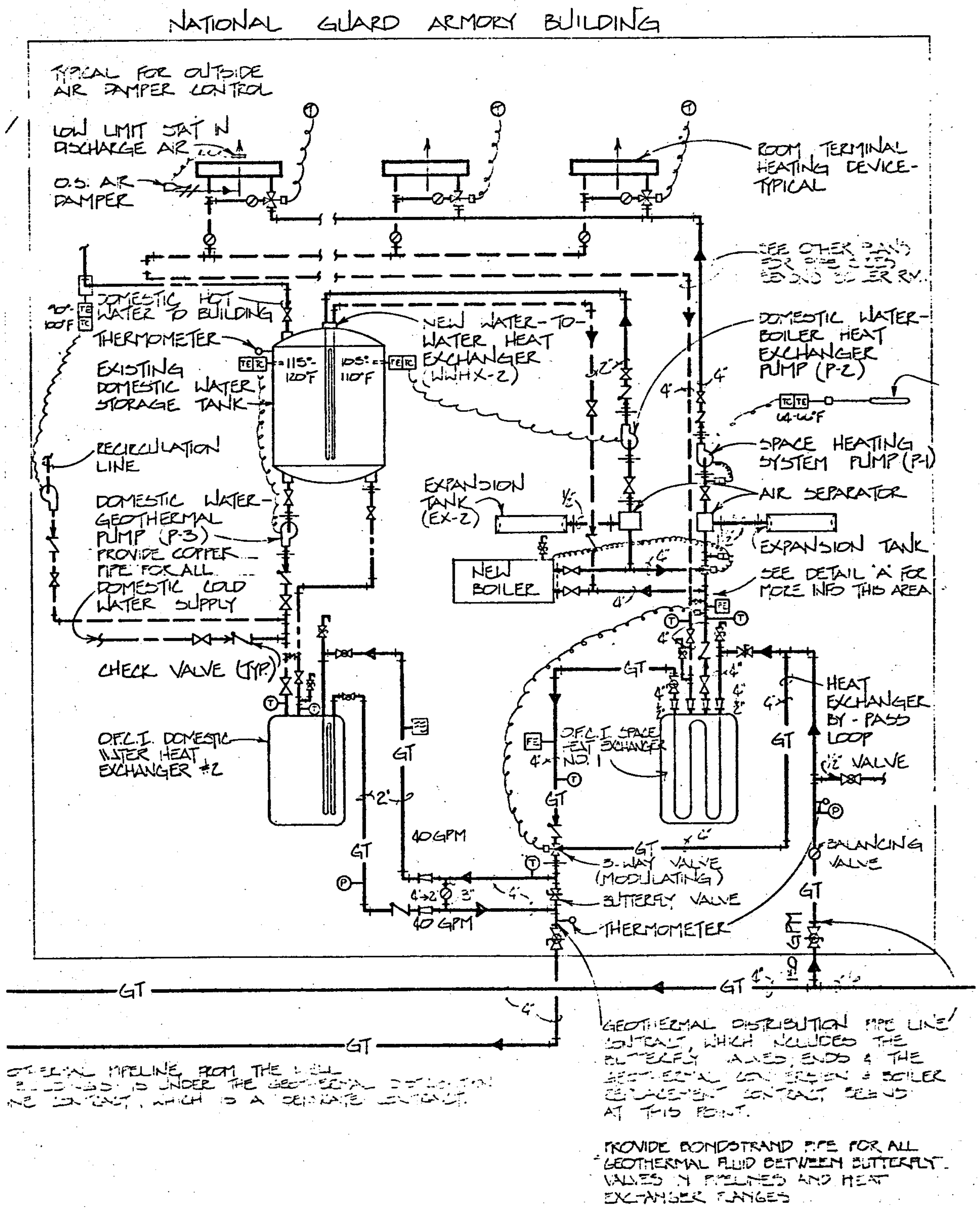

NATIONAL GUARD ARMORY BUILDING
TYPICAL FOR OUTSIDE AIR DAMPER CONTROL
LOW LIMIT STAT IN DISCHARGE AIR
O.S. AIR DAMPER
ROOM TERMINAL HEATING DEVICE-TYPICAL
DOMESTIC HOT WATER TO BUILDING
THERMOMETER
EXISTING DOMESTIC WATER STORAGE TANK
115°-120°F
105°-110°F
NEW WATER-TO-WATER HEAT EXCHANGER (WWHX-2)
DOMESTIC WATER-BOILER HEAT EXCHANGER PUMP (P-2)
SPACE HEATING SYSTEM PUMP (P-1)
AIR SEPARATOR
RECIRCULATION LINE
DOMESTIC WATER-GEOTHERMAL PUMP (P-3)
PROVIDE COPPER PIPE FOR ALL DOMESTIC COLD WATER SUPPLY
EXPANSION TANK (EX-2)
EXPANSION TANK
NEW BOILER
SEE DETAIL 'A' FOR MORE INFO THIS AREA
CHECK VALVE (TYP.)
O.F.C.I. DOMESTIC WATER HEAT EXCHANGER #2
O.F.C.I. SPACE HEAT EXCHANGER NO. 1
HEAT EXCHANGER BY-PASS LOOP
1/2" VALVE
BALANCING VALVE
3-WAY VALVE (MODULATING)
BUTTERFLY VALVE
THERMOMETER
40 GPM
GT
PROVIDE BONDSTRAND PIPE FOR ALL GEOTHERMAL FLUID BETWEEN BUTTERFLY VALVES IN PIPELINES AND HEAT EXCHANGER FLANGES

Figure 2

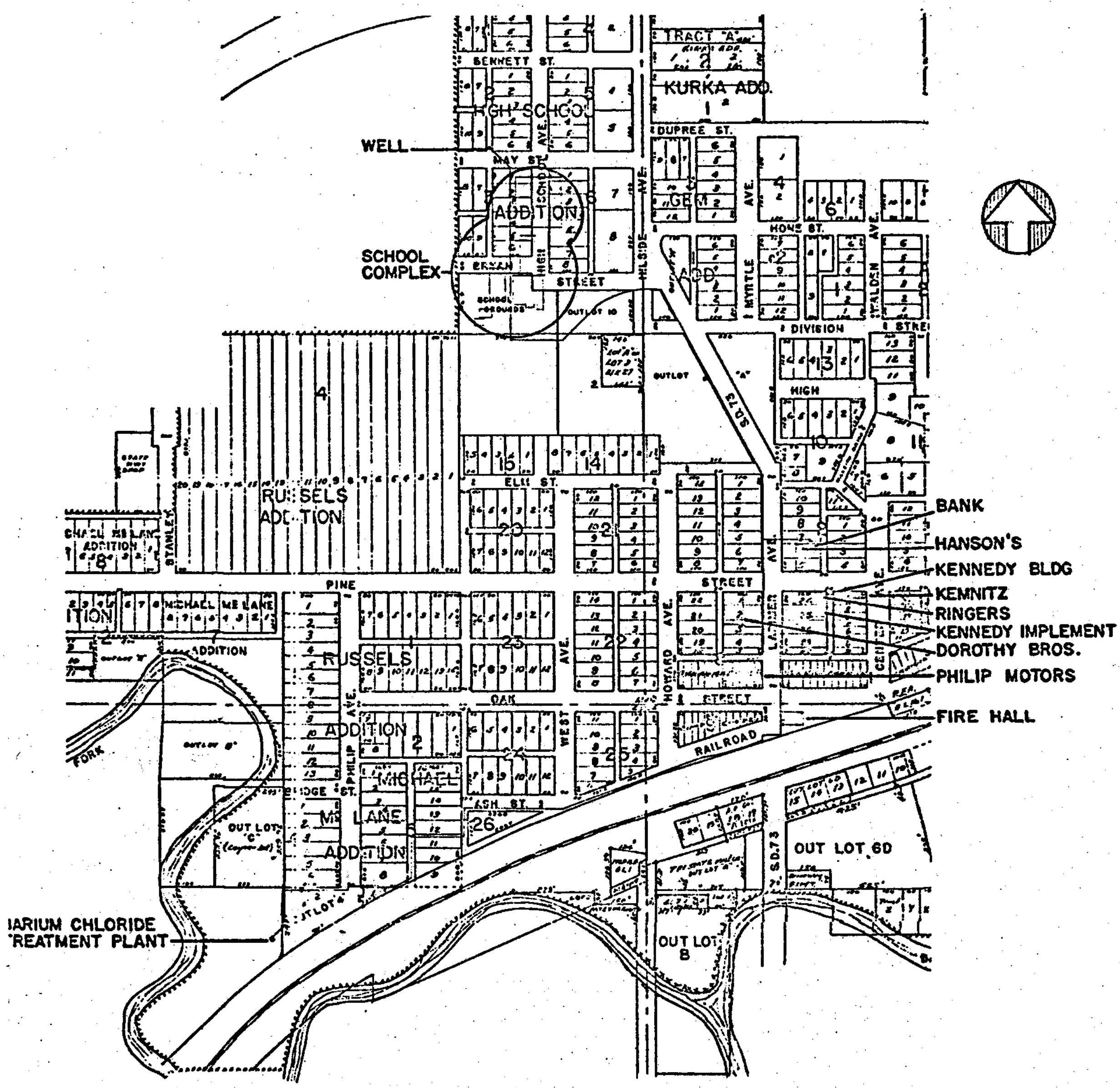
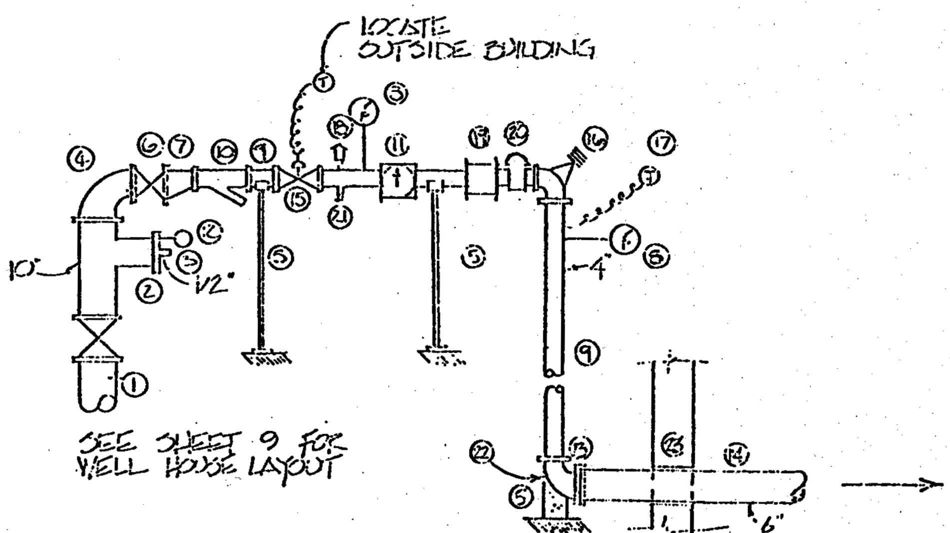

WELL
SCHOOL COMPLEX
BANK
HANSON'S
KENNEDY BLDG
KEMNITZ
RINGERS
KENNEDY IMPLEMENT
DOROTHY BROS.
PHILIP MOTORS
FIRE HALL
IARIUM CHLORIDE
'REATMENT PLANT
KURKA ADD.
RUSSELS ADDITION
OUT LOT 6D
OUT LOT B
RAILROAD

Figure 3

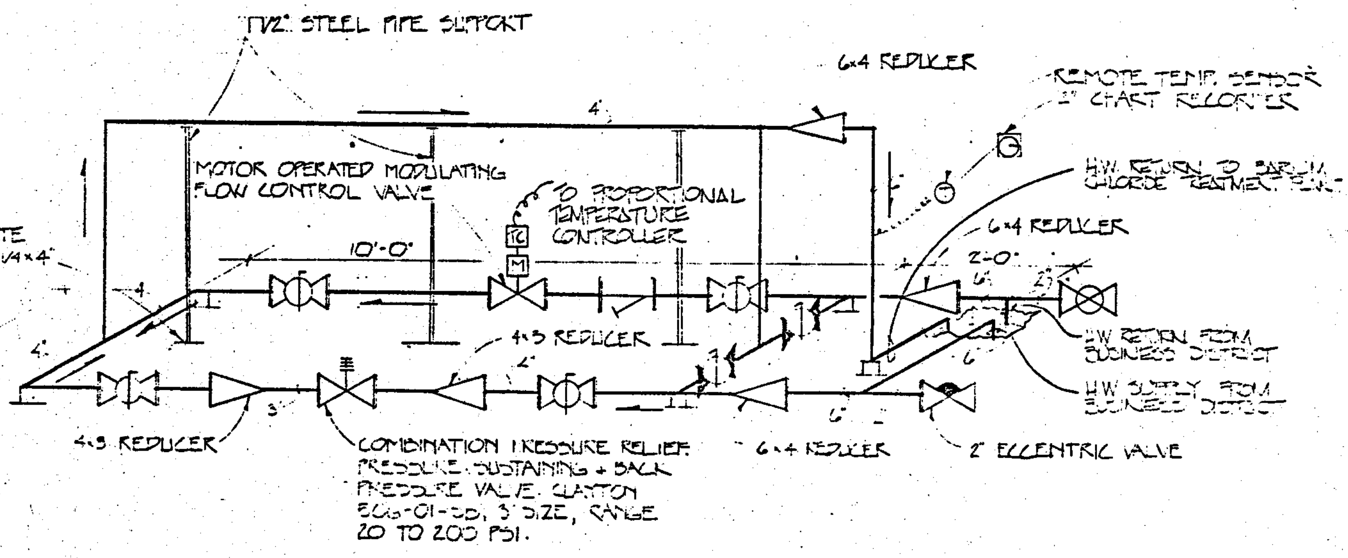
LEGEND

① EXISTING 10" BLACK IRON PIPE + VALVE FROM WELL
② EXISTING BLIND FLANGE
③ NEW 1/2" TAP FOR PRESSURE RECORDER BY U.S.G.S.
④ EXISTING REDUCING ELBOW (10" TO 6")
⑤ 1 1/2" STEEL PIPE SUPPORT W/ 8" I.D. STEEL PIPE SUPPORT SADDLE & 12" × 12" × 1/4" BASE PLATE W/ (4) - 1/2" × 4" ANCHOR BOLTS
⑥ NEW VALVE, OWNER FURNISHED, CONT. INSTALLED
⑦ NEW ECCENTRIC REDUCER (6" TO 4")
⑧ NEW PRESSURE GAGE
⑨ NEW BLACK IRON PIPE
⑩ NEW STRAINER
⑪ NEW FLOW METER
⑫ EXISTING PRESSURE GAGE
⑬ NEW FLANGED FITTING
⑭ NEW FIBERGLASS REINFORCED PIPE
⑮ NEW 4" MOTOR OPERATED MODULATING FLOOD CONTROL VALVE W/REMOTE CONTROLLER
⑯ NEW PRESSURE REDUCING ANGLE VALVE CLAYTON 906-01-YCSJB, 4" SIZE RANGE 30 TO 300 PSI
⑰ REMOTE THERMOMETER
⑱ AIR VENT
⑲ DRESSER COUPLER
⑳ VACUUM BREAKER + VENT
㉑ 3/4" THREDLET + PLUG
㉒ 4"-6" REDUCING ELBOW
㉓ PIPE SLEEVE THROUGH WELL HOUSE WALL - CALK PERIMETER



WELL HEAD CONNECTION NO SCALE

Figure 4



WATER DISTRIBUTION SYSTEM NO SCALE

Figure 5

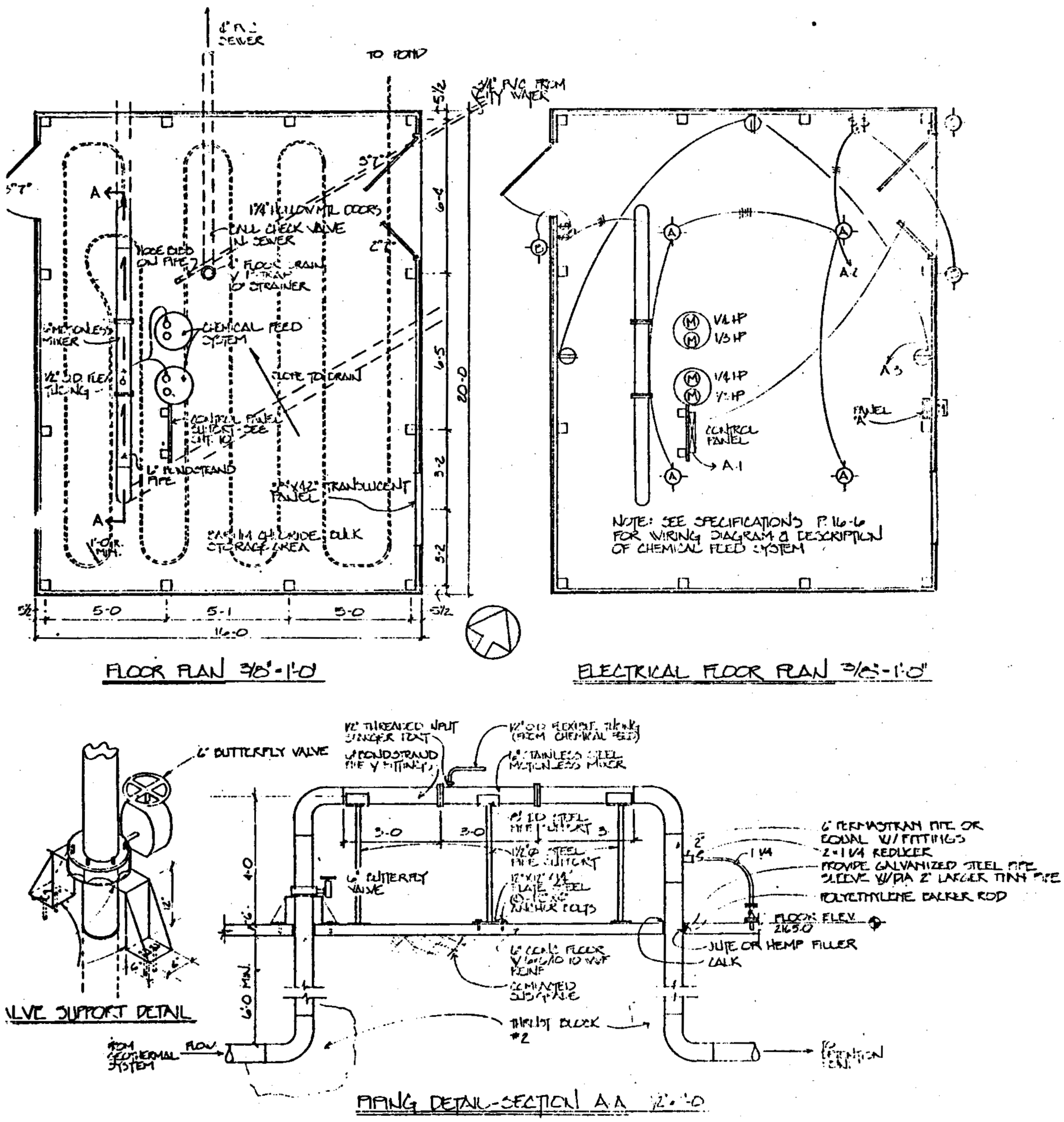
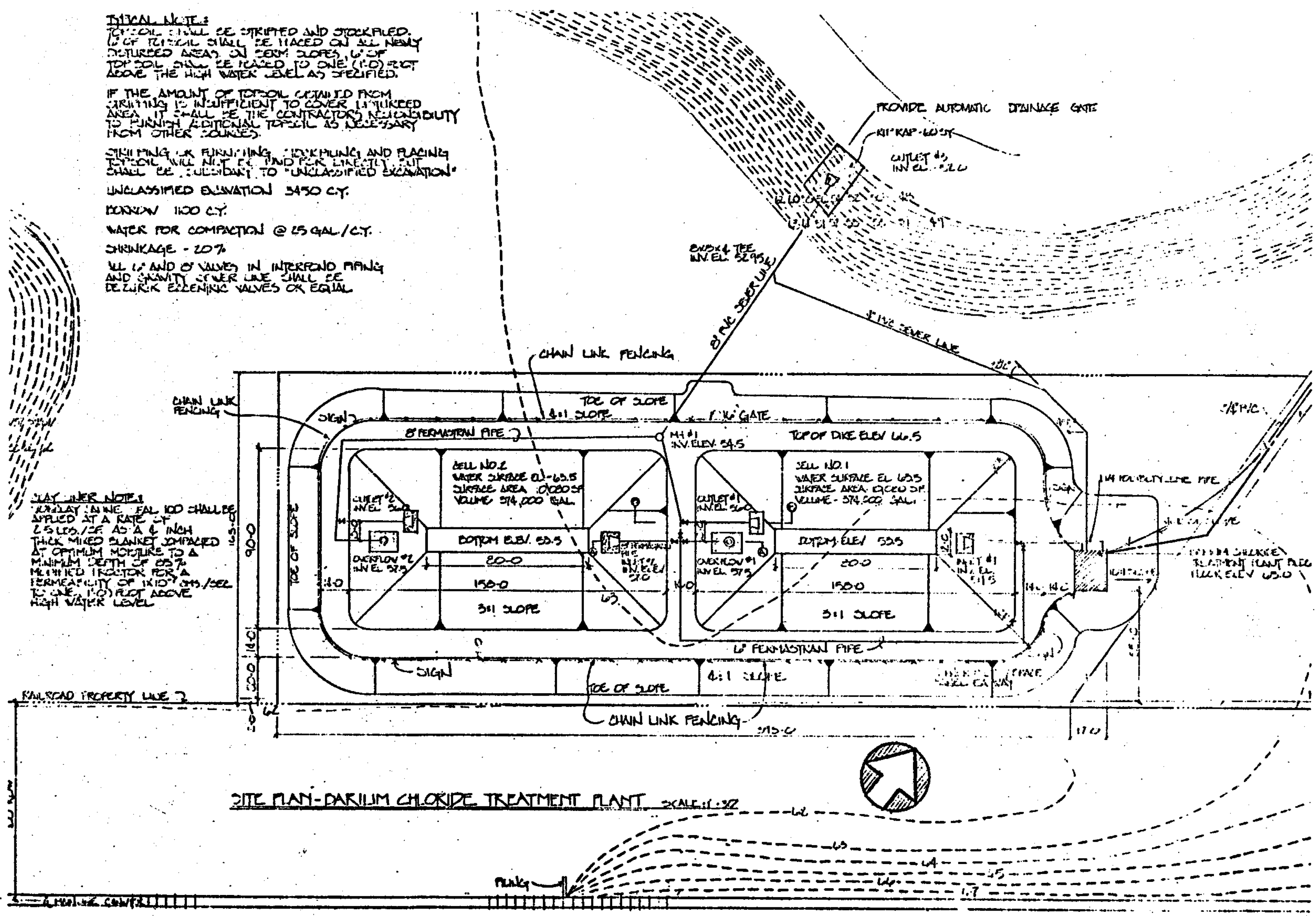

FLOOR PLAN 3/8"=1'-0"
ELECTRICAL FLOOR PLAN 3/16"=1'-0"
NOTE: SEE SPECIFICATIONS P. 16-6 FOR WIRING DIAGRAM & DESCRIPTION OF CHEMICAL FEED SYSTEM
CONTROL PANEL
PANEL "A"
CHEMICAL FEED SYSTEM
SLOPE TO DRAIN
6" BUTTERFLY VALVE
VALVE SUPPORT DETAIL
PIPING DETAIL-SECTION A-A
JUTE OR HEMP FILLER
CALK
POLYETHYLENE BACKER ROD
THRUST BLOCK #2
FLOW

Figure 6



TYPICAL NOTES:
TOPSOIL SHALL BE STRIPPED AND STOCKPILED. 6" OF TOPSOIL SHALL BE PLACED ON ALL NEWLY DISTURBED AREAS. ON BERM SLOPES, 6" OF TOPSOIL SHALL BE PLACED TO ONE (1'-0) FOOT ABOVE THE HIGH WATER LEVEL AS SPECIFIED.
IF THE AMOUNT OF TOPSOIL OBTAINED FROM STRIPPING IS INSUFFICIENT TO COVER DISTURBED AREA, IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO FURNISH ADDITIONAL TOPSOIL AS NECESSARY FROM OTHER SOURCES.
STRIPPING OR FURNISHING, STOCKPILING AND PLACING TOPSOIL WILL NOT BE PAID FOR DIRECTLY, BUT SHALL BE SUBSIDIARY TO "UNCLASSIFIED EXCAVATION"
UNCLASSIFIED EXCAVATION 3450 C.Y.
BORROW 1100 C.Y.
WATER FOR COMPACTION @ 25 GAL./C.Y.
SHRINKAGE - 20%
ALL 6" AND 8" VALVES IN INTERPOND PIPING AND GRAVITY SEWER LINE SHALL BE DEZURIK ECCENTRIC VALVES OR EQUAL
PROVIDE AUTOMATIC DRAINAGE GATE
CHAIN LINK FENCING
TOE OF SLOPE
4:1 SLOPE
GATE
TOP OF DIKE ELEV 66.5
8" PERMASTRAN PIPE
CELL NO.2
WATER SURFACE EL 65.5
VOLUME 574,000 GAL.
CELL NO.1
WATER SURFACE EL 65.5
VOLUME 574,000 GAL.
BOTTOM ELEV. 55.5
20-0
150-0
3:1 SLOPE
6" PERMASTRAN PIPE
SIGN
CLAY LINER NOTE:
HIGH WATER LEVEL
RAILROAD PROPERTY LINE
SITE PLAN - BARIUM CHLORIDE TREATMENT PLANT

Figure 7

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